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ECBC-TR-766

DEVELOPMENT OF A PORTABLE SENSITIVE EQUIPMENT DECONTAMINATION SYSTEM

VOLUME I – COMMERCIAL CANDIDATES MATERIALS EVALUATION (CHEMICAL AGENT STUDIES)

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14. ABSTRACT

The objective of the study was to evaluate commercial off the shelf materials to develop a decontamination method that is effective against a broad spectrum of agents (chemical, biological, Toxic Industrial Materials), compatible with vehicle/aircraft interior material, man-portable, simple to use with rapid and easy disposal, and inexpensive.

15. SUBJECT TERMS

Wipes	Decontaminant	Antibacterial	Agent	Mandrel
CARC	GD	HFE	HD	Vapor
ACAMS	DAAMS	VX	Carbon Fiber	Agent

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PREFACE

The work described in this report was authorized under Contract No. 04-098-D-0014-022-01. The work was started in April 2001 and completed in December 2004.

This report was published through the Technical Releases Office; however, it was edited and prepared by the Decontamination Sciences Branch, Research and Technology Directorate, U.S. Army Edgewood Chemical Biological Center.

The work described in this report was performed prior to the development of the 2007 Source Document. Therefore, different test methodology and calculation procedures were used that do not necessarily agree with the current procedures.

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VOLUME I – COMMERCIAL CANDIDATES MATERIALS EVALUATION (CHEMICAL AGENT STUDIES)

1. SUMMARY

This is the final report on the laboratory work conducted by Southern Research Institute (SRI) and Entropic Systems, Inc. (ESI), to develop a Portable (Block III) Sensitive Equipment Decontamination System. The work was conducted over the period of April 2001 through September 2003 under SciTech Services, Inc., subcontracts 01-98-D-0014-020 and 02-98-D-0014-022 under U.S. Army Prime Contract DAAD13-98-D-0014, D.O. 0020 and D.O. 0022. ESI's portion of the work was conducted under subcontract to Southern Research Institute under SRI contract numbers SC-00183 and SC-00193.

Under the JSSED Block III Sensitive Equipment Decontamination Program, the effect of dry and solvent-moistened wipes on the removal of chemical agents (CA) from surfaces was systematically studied. The studies were conducted using specialized automated rotary and linear wipe test systems developed under the program. A variety of dry and solvent-moistened wipes were evaluated on a range of surface types that were contaminated with droplets of neat CA agent—HD, TGD, or VX. The test surfaces evaluated included stainless steel, aluminum, Chemical Agent Resistant Coating (CARC)-painted panels, alkyd-painted panels, polyethylene, polycarbonate, and nylon webbing.

The objective of the study was to evaluate commercial off the shelf (COTS) materials to develop a decontamination method that is effective against broad spectrum of agents (chemical, biological, Toxic Industrial Materials (TIM)), compatible with vehicle/aircraft interior material, man-portable, simple to use with rapid and easy disposal, and inexpensive. A two-tiered approach was used to meet this objective:

1. Wipe test studies, with neat CA agents (HD, TGD, and VX), were conducted on a range of test surfaces conducted by Southern Research Institute.
2. Concurrent method Development and simulant studies were performed under subcontract to Southern Research Institute by Entropic Systems, Inc. (ESI), with fluorescent diethyl phthalate (DEP), a VX simulant.

This evaluation report describes the live agent decontamination wipe tests conducted at SRI using automated rotary and linear wipe test systems with the agents HD, TGD, and VX on a range of test surfaces—aluminum, CARC, alkyd paint, nylon webbing, polyethylene, and polycarbonate.

The most effective overall decontamination wipe system was a woven, activated carbon fabric wipe, pre-moistened with a commercial ethoxy-nonafluorobutane solvent (3M Novec™ HFE-7200). This wipe system effectively removed from 90% (% by weight determined from solvent extraction) to greater than 99% of the surface agent contamination on non-absorptive and low-agent-absorptive test surfaces in tests with HD, TGD, and VX. Dry activated carbon fiber wipes alone removed greater than 99% of HD surface contamination from non-absorptive aluminum surfaces. The decontamination efficacy results of the activated carbon fiber wipe system were equal or superior to results obtained in control tests with the reactive sorbent in the M295 Individual Equipment

Decontamination Kit, in the M100 Sorbent Decontamination System, and in comparison tests with magnesium oxide nanoparticle powder.

On non-absorptive surfaces, limited vapor off-gas testing with HD demonstrated that HD vapor concentrations over a HD-contaminated non-absorptive aluminum surface can be reduced to near or below 1.0 Time Weighted Average (TWA) (the allowable exposure limit at the time the of the test program) after wiping.

GD vapor concentrations over a TGD-contaminated non-absorptive aluminum surface can be reduced to the same absolute concentration levels (in terms of mass per unit volume, mg/m^3) as HD. But because the allowable exposure level of GD is 100 times lower than the allowable exposure level for HD [on the basis of the Airborne Exposure Limit (AELs) in AR 385-61 of 0.003 mg/m^3 for HD and 0.00003 mg/m^3 for GD], surface wiping most likely would have difficulty reducing the mass of GD enough to become below the AEL. In addition, because the AEL for VX is a factor of three times lower than GD, the decision was made not to include GD and VX vapor monitoring as a screen for these candidate wiper materials.

2. INTRODUCTION

This is the final report on the laboratory work, conducted by SRI and ESI, to develop a Block III Sensitive Equipment Decontamination System with oversight and in cooperation with U.S. Army Edgewood Chemical and Biological Center ECBC). The work was conducted over the period from April 2001 through September 2003, under SciTech Services, Inc., subcontracts 01-98-D-0014-020 and 02-98-D-0014-022, under U.S. Army Prime Contract DAAD13-98-D-0014, D.O. 0020, and D.O. 0022. ESI's portion of the work was conducted under subcontract to Southern Research Institute under SRI contract numbers SC-00183 and SC-00193.

This is the first (Volume I) of two reports (Volumes I and II) that summarize the evaluation and development of a wipe material to meet sensitive equipment and vehicle interior Joint Service (JS) requirement needs, as defined within the JS Operational Requirements Documents (ORD) for Sensitive Equipment Decontamination and Platform Interior Decontamination. This report and Volume II, demonstrate an effort to evaluate COTS and military materials, applicable to the ORD definitions for portable decontamination system, which would support a thorough decontamination efficacy process and provide immediate and operational decontamination efficacy. In addition to a COTS/military materials comparison, Volume I also measures the decontamination efficacy of chemical agent by these material processes, from a variety of sensitive type material surfaces, as a function of the total mass removed. The mass removed was determined by solvent extraction and diffusion by vapor analysis. Volume II summarizes similar work conducted using chemical agent simulants.

Volume I describes the live agent decontamination wipe tests conducted using automated rotary and linear wipe test systems with the agents HD, TGD, and VX on a range of test surfaces—aluminum, CARC, alkyd paint, nylon webbing, polyethylene, and polycarbonate.

Volume II describes the work specific to the development of activated carbon fiber fabric as a portable sensitive equipment/interior decontamination system. Within the Volume II report, the test objectives are defined from interpretation of the JSSED and Joint Platform Interior Decontamination (JPID) ORD Key Performance Parameters (KPP), for a portable decontamination system. The Volume II report provides the test data, results, and conclusions demonstrating the Area Cost Factor (ACF) fabric wipe development, focusing on the adsorptive processes and surface decontamination efficacy for select materials

3. BACKGROUND

The Joint Service Integration Group defined the requirements for a system that would provide the ability to decontaminate chemical and biological agents from sensitive equipment (avionics, electronics, electrical, and environmental systems and equipment), aircraft/vehicle interiors (during flight/s\ground/shipboard operations), and assorted cargo. The U.S. Army ECBC was the lead acquisition agency for this program.

This JSSED System development was broken down into three distinct, progressively increasing capability "blocks" to reduce technology and financial risk.

- The Block I system addressed the ability to successfully decontaminate sensitive equipment without affecting operation readiness, reliability, or maintainability.
- The Block II system addressed the ability to decontaminate the interiors of aircraft/vehicles, requiring unique volumetric processing of all aircraft/vehicles current or planned for U.S. inventory.
- The Block III system addressed the ability to decontaminate aircraft and vehicle interiors during flight, ground, or shipboard operations, also known as decontamination "on-the-move."

The work conducted under the study described in this report was a feasibility study. The preliminary development program for a Block III sensitive equipment decontamination system/process was based on the use of solvent-moistened adsorptive wipes for the physical removal of chemical-warfare agents from surfaces. For purposes of comparison, the decontamination tests were also performed with the decontamination powder used in the Army's current M 295 decontamination kit and M100 Sorbent Decontamination System, and with reactive nanoparticle powders, a potential next-generation sorbent decontaminant.

The decontamination system/process will provide on-demand decontamination without adverse effects on the crew, mission, or platform performance. Based on the technology assessment performed, the most feasible solutions for Block III systems to date are spot decontamination "kits" for sensitive equipment and interiors, which incorporate solvent wash and sorbent decontamination components. These "kits" would include one or more solvents compatible with electronics and sensitive materials for the dissolution of agent contamination, and sorbent decontamination materials for the removal of the dissolved agent from the surface.

These kits would rely on physical removal of the agent from the contaminated surface by dissolution in a solvent, followed by both capture and storage of the contaminated solvent, or by adsorption of the dissolved contaminant on a solid substrate. In either case, the contaminated material would be safely isolated, and ultimately disposed of, at an appropriate off board site.

The technologies evaluated under the program were:

- Adsorptive Wipe – Solvent Moistened Wipes
- Solvent Spray and Wipe
- Sorbent Powder and Wipe

SRI and ESI worked closely with and under the guidance of ECBC in the performance of this effort.

In February 2006, Version 1.1 of the Joint Platform Interior Decontamination (JPID) Capability Development Document (CDD) was released. The original ORDs for JSSED and JPID were converted to CDDs. The Joint Material Decontamination System (JMDS) is expected to meet the decontamination requirements of both CDDs for their respective items. At some point, a Capability Production Document will incorporate all of the requirements. While JMDS was intending to incorporate three independent variant decontamination systems in order to meet the requirements of both CDDs, this issue was not resolved at the time of this writing. The program objective was to develop a wipe that would provide immediate and operational decontamination capabilities for contamination reduction, and was also safe for use on electronic equipment. This technology has potential application to the JSSED program to provide the warfighter with a capability to significantly reduce the initial contamination by 90%.

In April 2006, a Technology Transition Agreement (TTA) for the solvent wipe was initiated. The TTA is a living document and serves as a Memorandum of Agreement (MOA) between the Joint Science & Technology Office (JSTO) (technology developer) and the Joint Program Manager (JPM) (intended receiver of a technology or capability developer). The wipe is described as a "Portable Decontaminant for Vehicle Interiors" (PDVI), which is capable of removing gross surface chemical and biological agent contamination from sensitive materials and complex surfaces in vehicle interiors.

4. TECHNICAL APPROACH

The technical approach to the task was a joint effort between SRI and ESI, in close collaboration with the ECBC program manager, Mr. Brian MacIver.

The ESI examined the fundamental parameters of surface contaminant removal by a wet solvent wipe system, using automated wipe test systems that were designed and fabricated for the program. The ESI studies examined the quantitative removal of diethylphthalate (DEP), a VX simulant, doped with a fluorescent dye from aluminum test surfaces.

The SRI conducted live agent decontamination tests, using the automated wipe test systems with the chemical agents HD, TGD, and VX on a range of test surfaces—aluminum, CARC, alkyd paint, nylon webbing, polyethylene, and polycarbonate.

5. MATERIALS AND EQUIPMENT

5.1 Computer-Controlled Linear- and Rotary-Wiping Devices

To evaluate the effect of different parameters on surface contaminant removal by wiping, and to eliminate wiping variability introduced by hand wiping, ESI, with technical design input from SRI, designed and had fabricated two computer-controlled wiping systems: a linear-wiping system and a rotary-wiping system. With the linear-wiping system, the wipe was mechanically pulled horizontally over a contaminated area. With the rotary-wiping system, the wipe was rotated in place over a contaminated area.

A photograph of the rotary-wiping system, with a non-adsorptive wipe material mounted on the rotary-wiping mandrel, is shown in Figure 1. A photograph of the linear-wiping system is shown in Figure 2.

Each system was powered remotely by a computer-controlled stepper motor, which provided control of the speed of the mechanical motion of the wipe, constancy of wiping motion, and duration of wiping.

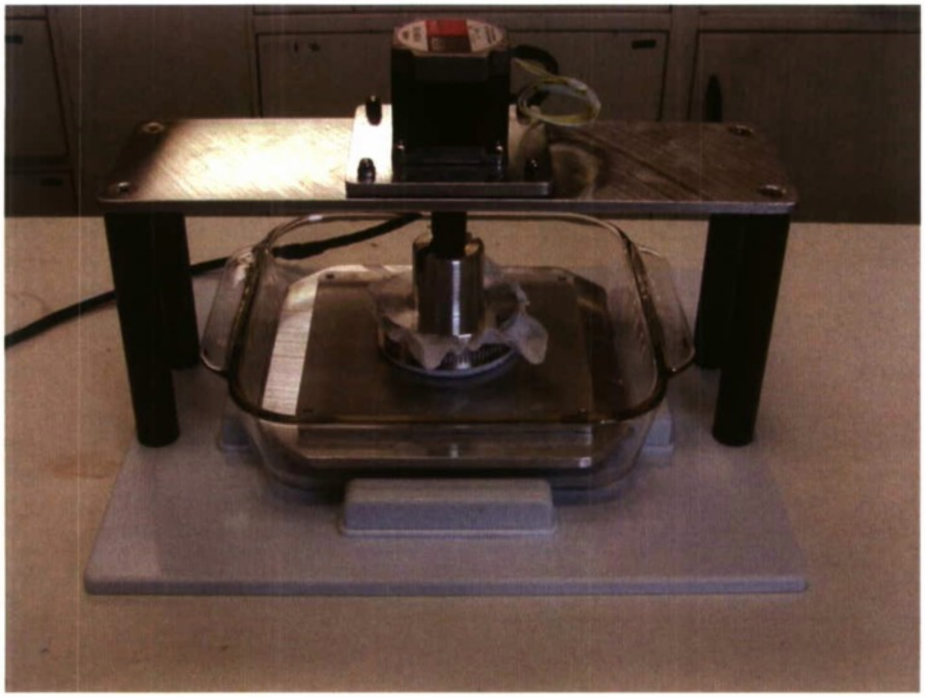

Figure 1. Photograph of the rotary-wiping test apparatus.

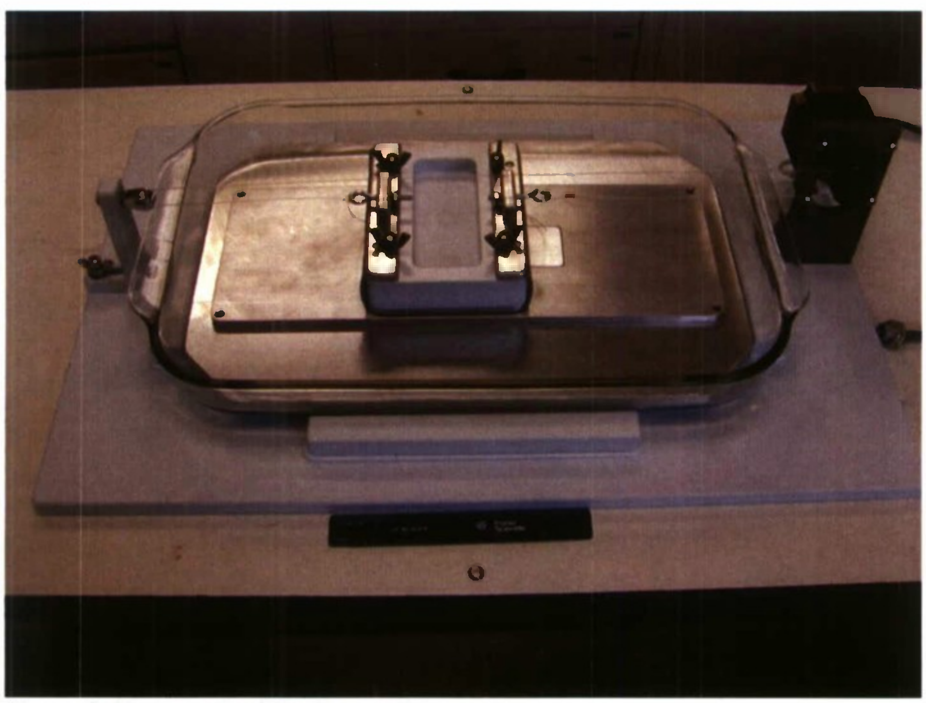

Figure 2. Photograph of the linear-wiping test apparatus.

The two wiping systems were sized to allow the wiping experiments to be performed in a standard 10 in. wide by 20 in. long, 4 qt Pyrex baking dish.

In both systems, the vertical load on the wipe was established solely by the weight of the wipe base and of any auxiliary weight placed on the base. In the rotary-wiping device, a pin drive mechanism was used to decouple the weight of the drive motor from the rotating wipe base.

A more detailed discussion of the design of the linear- and rotary-wiping systems, along with design sketches, parts lists, and details of the construction materials for the wiping systems are given in Volume II of this report. The instruction manuals for the two wiping systems, prepared by ESI, are included as Attachment A of Volume II.

After the receipt, assembly, and inspection of the wiping devices, SRI had five additional rotary-wiping mandrels (3 in. diameter, 6061 aluminum alloy, as shown in Figure 5 of Appendix A) and 12 additional square aluminum test coupons (for the linear-wiping device) fabricated by Precision Industries, Inc., of Birmingham, AL.

The original baseplates on both the rotary and linear-wiping systems were designed and fabricated with 1.5 in. square cutouts for mounting 1.5 x 1.5 x 0.25 in. square aluminum coupons. The baseplate in the rotary-wiping system had a single cutout. The baseplate in the linear-wiping system had three cutouts. Subsequent testing was conducted with 2 x 2 x 0.125 in. CARC- and alkyd-painted stainless steel panels, which were provided by the Government. In order to conduct automated-wiping tests with these panels, additional baseplates were fabricated for the automated-wiping systems—one for the rotary-wiping system and one for the linear-wiping system. Each of the additional baseplates was fabricated with a single cutout. These additional baseplates were also used in the tests with polycarbonate and polyethylene test coupons, which were commercially pre-cut to the same dimensions as the CARC and alkyd stainless steel panels.

5.2 Wipe Materials

The materials described in this section (Figure 3) were among those tested with the wiping technology.

- KoTHmex AW 1101/1103: Woven activated carbon fiber (ACF) cloth manufactured by Taiwan Carbon Technology Co., Ltd., Nantuen Chiu, Taichung, 408 Taiwan, ROC. The properties of the ACF fabric are as listed in Table 1 below.

- KoTHmex AM 1132/1131: Activated carbon felt manufactured by Taiwan Carbon Technology Co., Ltd., Nantuen Chiu, Taichung, 408 Taiwan, ROC. The properties of the activated carbon felt are as listed in Table 1 below.

Table 1. Properties of activated carbon fabric and activated carbon felt.

Material	AW 1101	AW 1103	AM1131	AM1132
Material Form	**Plain Weave Fabric**	**Plain Weave Fabric**	**Felt**	**Felt**
Surface Area, m²/g	1100	1050	1100	1100
Total Pore Volume, mL/g	0.5-0.6	0.5-0.6	0.5-0.6	0.5-0.6
Avg. Pore Diameter, Å	19-20	19-20	19-20	19-20
Fabric Weight, g/m²	95-105	115	150	250
Fabric Thickness, mm	0.40-0.50	0.4	2.0	2.75
Fabric Width, cm	98-102	120	117	117
Decomposition Temp. °C	>500	>500	>500	>500

- 3M Scotch-Brite™ 2011 High Performance Cloth: Scotch-Brite™ 2011 is a commercial high performance microfiber cleaning cloth manufactured by the 3M Company. Typical properties of the cloth are listed in Table 2.

- 3M Scotch-Brite™ 2021/2021N High Performance Cloth: Scotch-Brite™ 2021 and 2021N (N=Natural) are white knitted cloths, each composed of a bi-component microfiber with serging on all sides. Scotch-Brite™ 2021N is a "natural" off-white unbleached cloth. Scotch-Brite™ 2021 is a bleached 2021N cloth with a white color. Typical properties of the cloths are listed in Table 2.

Table 2. Properties of Scotch-Brite™ high performance cloth.

Material	2011	2021/2021N
Property	Typical Value	Typical Value
Dimensions, cm	32 x 36	43.1 x 49.5
Thickness, mm	1.57	1.57
Weight, g	30.8	50
Fiber Type	Polyester and nylon	80% polyester/20% nylon
Tuft Density, number/cm²	37	37
Water Absorption, g water/g wipe	7.2	4.3
Oil Absorption, g oil/g wipe	7.1	4.4
Drag – glass (dry, kinetic coefficient)	0.85	0.85
Drag – formica (dry, kinetic coefficient)	0.41	0.41
Tear Resistance (6400 g pendulum) Machine Direction, g force Cross Direction, g force	 5570 4290	 5570 4290
Linting	Minimal	-

- Teri® Reinforced Wipers: Dry commercial four-ply, nylon-reinforced, 95%-recycled-paper wipes manufactured by Kimberly-Clark®. Obtained from Southern Research Institute stockroom.

- Lever 2000® Antibacterial Wipes: Commercial pre-moistened antibacterial wipes manufactured by the Lever Brothers Company and purchased locally. The wipes are moistened with a 0.15% aqueous solution of benzalkonium chloride, with less than 1% each of unspecified preservatives and fragrances/perfumes.

Scotch-Brite™ is a registered trademark of 3M Corporation, St. Paul, MN.
Teri® is a registered trademark of Kimberly-Clark, Dallas, TX.
Lever 2000® is a registered trademark of Lever Brothers Company, New York, NY.

- Swiffer® Wipes: Dry commercial Swiffer Disposable Refill Cloths, manufactured by Proctor and Gamble and purchased locally.

- Pledge® Grab-It Wipes: Dry wipes cut from commercial Pledge® Grab-It disposable mitts, manufactured by S.C. Johnson & Son, Inc., and purchased locally.

- Cutex® Simple Pad (non-acetone): Cutex® Simple Pads (non-acetone) are commercial pre-moistened felt pads in individual sealed packages. The listed ingredients of each pad are ethyl acetate, isopropyl alcohol, water, CDP conditioner, and fragrance.

- Clorox® Disinfecting Wipes – Lemon: Pre-moistened commercial non-woven wipes. The listed active ingredients are 0.145% n-alkyl dimethyl benzyl ammonium chloride and 0.145% n-alkyl dimethyl ethyl benzyl ammonium chloride. The solvent not specified, but is assumed to be primarily 1–5% aqueous isopropyl alcohol.

- Clorox® Disinfecting Wipes – Fresh: Pre-moistened commercial non-woven wipes. The listed active ingredients are 0.145% n-alkyl dimethyl benzyl ammonium chloride, 0.145% n-alkyl dimethyl ethyl benzyl ammonium chloride, and 1 to 5% isopropyl alcohol. The solvent not specified, but is assumed to be water.

- Bounty® Paper Towels: Bounty Big Roll.

- U.S. Safety Respirator Wipes (Alcohol Free): Commercial alcohol-free foil-packaged, pre-moistened towelettes, manufactured by U.S. Safety. The active ingredient in the wipe is a 0.4% aqueous benzalkonium chloride solution.

- Non-Woven Polyester Felt: Non-woven polyester felt—Southern Research Institute toxic Agent Facility stock roll manufactured by Fiber Taxis, Inc., and used for the fabrication of V-G conversion pads for DAAMS, ACAMS, and MINICAMS sampling and analysis.

- Professional Wypall® X70 Workhorse® Manufactured Rags: Kimberly-Clark® Professional Wypall® X70 Workhorse® Manufactured Rags are cloth-like Hydroknit non-woven composite wipes, which are manufactured using jets of water to bond soft absorbent paper fibers to polypropylene non-woven fabric.

Swiffer® is a registered trademark of Proctor and Gamble, Cincinnati, OH.
Pledge® is a registered trademark of S.C. Johnson & Son, Racine, WI.
Cutex® is a registered trademark of MedTech Laboratories, Inc. Irvington, NY.
Clorox® is a registered trademark of The Clorox Company, Oakland, CA.
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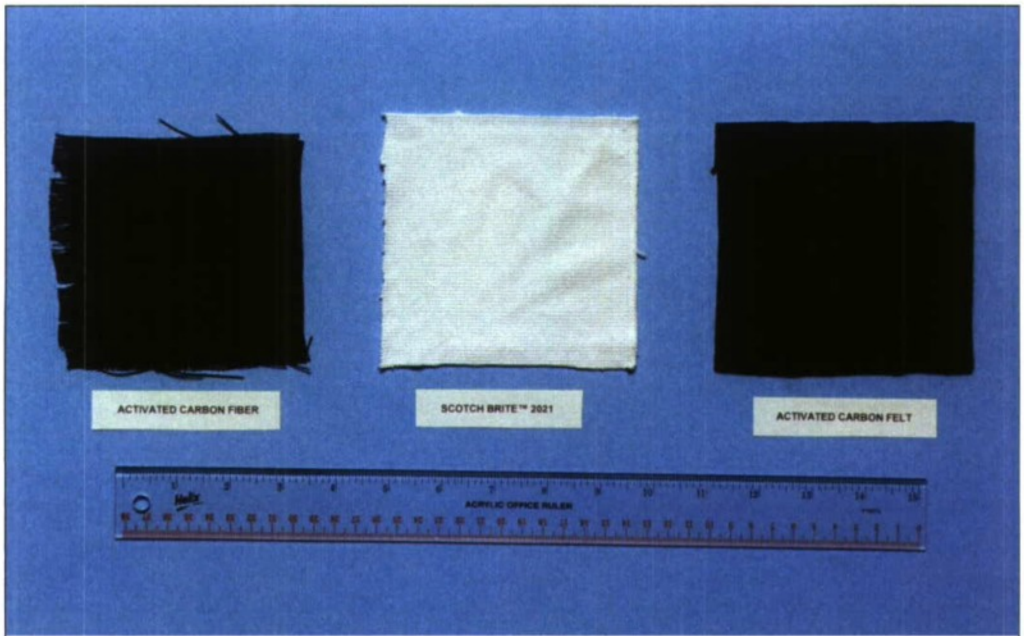
Wypall® and Workhorse® are registered trademarks of Kimberly-Clark, Dallas, TX.



Activated Carbon Fabric, Scotch-Brite™, and 2021 Activated Carbon Felt.

Figure 3. Photograph of swatches of the three most effective wipe materials evaluated in the study.

5.3 Test Surfaces/Substrates

The test surfaces/substrates, described in this section (Figure 4 and Figure 5), were among those tested with the wiping technology.

- Aluminum: The majority of the tests were conducted with 1.5 x 1.5 in. square, 0.25 in. thick aluminum coupons cut from stock material of the AL 2026, Type 2, sheets. The surfaces of the aluminum coupons were machined smooth, but were not polished.

- Stainless Steel: The preliminary manual rotary tests were conducted with a set of machined stainless steel disks. Each stainless steel coupon was a 7 cm diameter x 3 mm thick cylindrical disk, with flat machined (but not polished) surfaces that were cut from stock of a type 304 grade sheet.

- CARC: CARC-painted stainless steel panels were prepared and furnished for use in the wiping tests by ECBC. Each panel was 2 x 2 in. square, 0.125 in. thick and was treated with zinc phosphate. One surface of the panel was covered with 1.0 mil of epoxy primer conforming to MIL-P-52192, and 2.0 mils of polyurethane topcoat conforming to MIL-C-53039A.

- Alkyd: Alkyd-painted stainless steel panels were prepared and furnished for use in the wiping tests by ECBC. Each panel was 2 x 2 in. square, 0.125 in. thick. One surface of the panel was painted with alkyd topcoat per MIL-E-52798A (olive green).

- Nylon Webbing: A sheet of red nylon duck cloth (MIL-C-7219F) was furnished for use in the tests by ECBC. Information on the type and class of the cloth is not known. The sheet of nylon webbing was cut into 2 x 2 in. squares for testing.

- Polyethylene: Sorbent-powder scratch tests and a limited set of wipe tests were conducted on a set of high-density polyethylene coupons purchased from AAA Plastics of Birmingham, AL. Each coupon/panel was purchased pre-cut to dimensions of 2 x 2 in. square x 0.125 in thick.

- Polycarbonate: Sorbent-powder scratch tests and a limited set of wipe tests were conducted on a set of polycarbonate coupons purchased from AAA Plastics of Birmingham, Alabama, as clear polycarbonate, 0.125 in thick. Each coupon/panel was purchased pre-cut to dimensions of 2 x 2 x 0.125 in.

- First Surface Mirror: Sorbent-powder scratch tests were conducted on a set of first surface mirrors purchased from Edmond Scientifics, Tonawanda, NY (part # 68-1289). The dimensions of each mirror were 38 x 38 mm square x 3.2 mm thick.

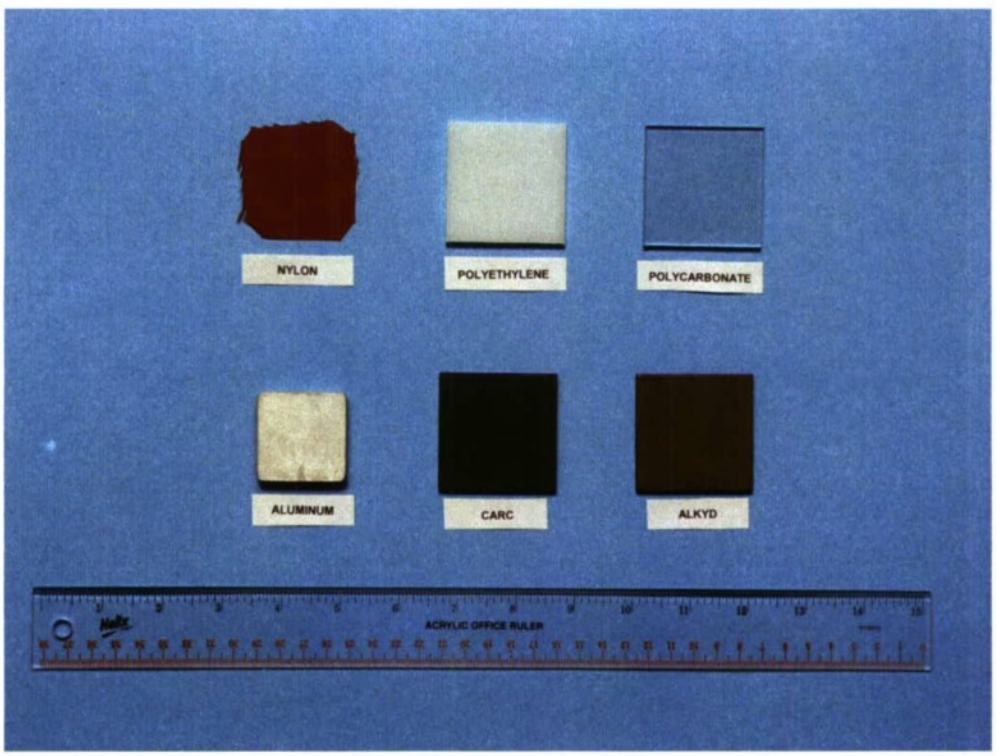


Figure 4. Photograph of test surfaces/panels evaluated.

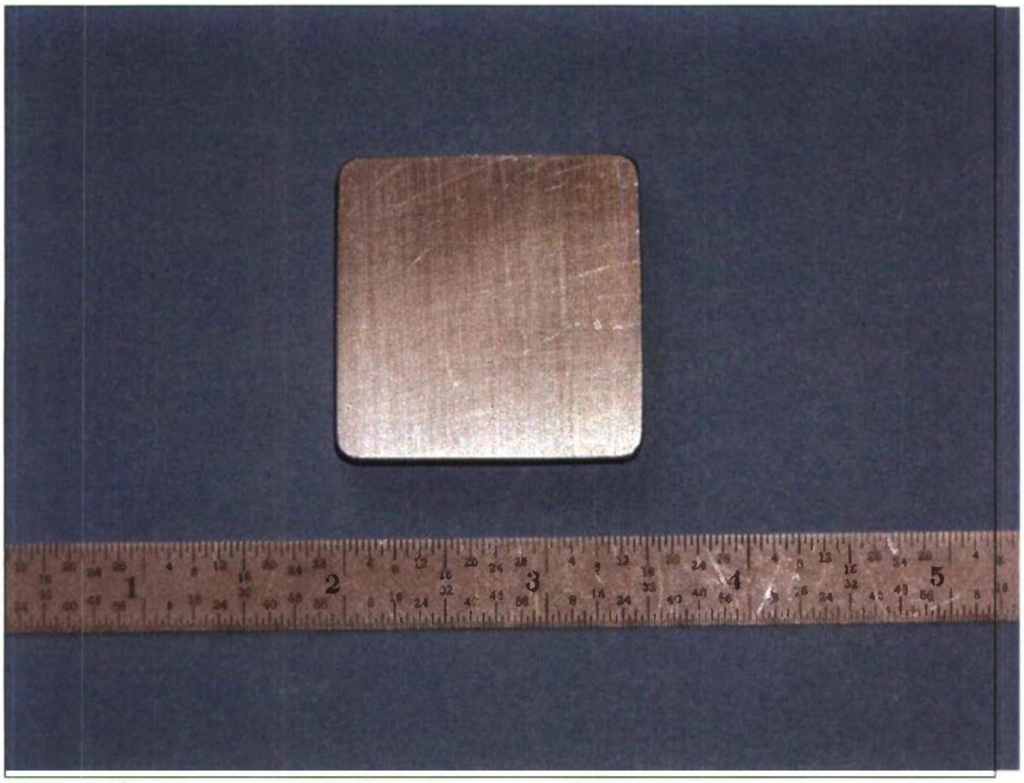


Figure 5. Close-up photograph of aluminum test surface.

5.4 Solvents/Decontaminants

The solvents/decontaminants described in this section were among those used with the wiping technology.

- HFE-7200: HFE-7200 is ethyl nonafluorobutyl ether ($C_4F_9OC_2H_5$), a hydrofluoroether (HFE) manufactured by the 3M™ Company as a non-ozone-depleting solvent under the trade name Novec™ Engineered Fluid HFE-7200. HFE-7200 is a clear, colorless, low-odor, volatile liquid that is nonflammable, essentially nontoxic, generally non-hazardous to personnel, and compatible with a wide range of metals, plastics, and elastomers. HFE-7200 has a low environmental impact, and, while it is highly volatile, HFE-7200 evaporates slowly enough to be useful as a solvent in an adsorptive wipe.

- HFE-71IPA: HFE-71IPA is an azeotropic mixture consisting of 95.5% (by weight) HFE-7100 (methyl nonafluorobutyl ether) and 4.5% (by weight) isopropanol. It is manufactured by the 3M™ Company as a non-ozone-depleting cleaning solvent under the trade name Novec™ Engineered Fluid HFE-71IPA. HFE-71IPA has physical, toxicity, and environmental properties similar to those of HFE-7200, but has the potential for enhanced HD solubility because of the IPA component of the azeotrope.

- Isopropanol: Isopropyl alcohol (IPA) has been a common solvent with good solubility properties for CA agents.

- Hexane: n-Hexane is an excellent HD solvent.

- M295/M100 Sorbent Powder: The M295/M100 sorbent powder is a surface-modified, activated alumina-reactive sorbent powder (A-200-SiC-1005S), used as the adsorbent resin in the M295 Individual Equipment Decontamination Kit, and in the M100 Sorbent Decontamination System. The powder was supplied by ECBC. The powder was used in decontamination-efficacy control tests as a reference decontaminant to enable comparison of the efficacies of the candidate wipe materials.

- MgO Nanoparticle Powder: NanoActive® Magnesium Oxide Plus is a high, specific surface area, nanoparticle powder ($\geq$ 600 m^2/g) manufactured by NanoScale Materials, Inc., 1310 Research Park Dr., Manhattan, KS 66502. The MgO Plus has small crystallite size, high porosity, and high chemical reactivity at room and elevated temperatures. The powder was supplied by ECBC.

- Chemical Agents (CA): The neat agents used in the wipe tests to contaminate the test surfaces and to prepare agent standard solutions in isopropyl alcohol for use in instrument calibration, were provided and authorized for use by ECBC under the terms of Bailment Agreement DAAD13-00-H-0009.

The lot numbers and Government-reported purities of the neat agents used in the study are listed in Table 3.

Table 3. Chemical agents used in study.

Agent	Lot Number	Purity
HD	010503-1	97.5%
HD	010503-2	97.5%
HD	010503-3	97.5%
HD	011003-1	97.5%
VX	020605-4	96.0%
TGD	000705-1	99.0%
TGD	012401-3	99.0%
TGD	011003-1	99.0%

The neat agents were adjusted for purity in the preparation of standard solutions for instrument calibration. The weight of neat agent deposited on the test surfaces in the wipe tests was not adjusted for agent purity.

6. WIPE TEST PROCEDURES

6.1 Manual Rotary Wiping for Dry and Solvent-Moistened Wipes

Initially, manual rotary-wiping tests were conducted while the automated rotary- and linear-wiping test apparatuses were being fabricated. The manual wiping procedures used in the tests were designed to simulate the rotary-wiping procedures that would subsequently be used in tests with the automated rotary-wiping test apparatus.

Each test was conducted at room temperature and ambient relative humidity. In a given test a flat, cylindrical stainless steel substrate was contaminated with 10 mg of neat HD. The agent-contaminated surface was then manually wiped with a dry wipe, with a wipe moistened (but not saturated) with HFE-7200, or with a commercial wipe that was already moistened with a solvent (as received).

Each stainless steel substrate was a 7 cm diameter x 3 mm thick, cylindrical disk with a flat machined surface. Either five 2 µL droplets or eight 1.25 µL (approximate) droplets of neat HD (a total of 10.0 mg) were placed in a uniform pattern in the center of a 1 in. diameter area of the stainless steel surface, using a micropipettor.

In each test, a square swatch of the candidate wiping material (typically 4.5 x 4.5 in.) was fastened tautly with plastic cable ties to one end of a 1 lb aluminum cylinder (2-1/2 in. diameter and 2-1/16 in. long).

In each test with a dry wipe or with a pre-moistened wipe, the cylinder with the attached wipe was placed gently down on the stainless steel substrate, with the wipe contacting the contaminated surface. The cylinder was then rotated clockwise by hand one revolution over a 10 s period. The cylinder was then rotated counterclockwise one revolution over a 10 s period. The wipe remained in contact with the surface at all times during the wiping procedure. Care was taken not to impart any manual downward force on the cylinder during its rotation.

In each test with HFE-7200, the dry wipe mounted on the aluminum cylinder was uniformly sprayed with HFE-7200 from a pressurized aerosol can of the solvent until the wipe was moist, but not saturated, with HFE-7200. (The HFE-7200 was uniformly sprayed onto the surface of the wipe for approximately 2 s from a distance of about 1 in.) The cylinder was then placed gently down on the stainless steel substrate with the HFE-7200-moistened wipe contacting the contaminated surface. The elapsed time between the spraying of the wipe with HFE-7200 and the contacting of the wipe with the contaminated surface was just a second or two to minimize solvent evaporation. The cylinder was then rotated clockwise by hand one revolution over a 10-s period. The cylinder was then rotated counterclockwise one revolution over a 10 s period. The wipe remained in contact with the surface at all times during the wiping procedure. Care was taken not to impart any manual downward force on the cylinder during its rotation.

After the completion of each set of wipe sequences, each contaminated wipe was removed from the aluminum cylinder and placed in a sodium hypochlorite decontaminant solution. Each stainless steel disk was placed in sample jar containing 25 mL of isopropyl alcohol (IPA) to extract any residual agent from the disk. After a 60 min extraction period, the IPA extract was analyzed for residual HD by Gas Chromatography- Flame Photometric Detector (GC-FPD). The GC parameters used in the analyses are summarized in Section 6.5.5. The minimum quantifiable amount of HD remaining on a given panel was 12 µg (out of the 10,000 µg initially deposited on each panel).

6.2 Automated Rotary-Wiping Procedures for Dry and Solvent-Moistened Wipes

The automated rotary-wiping tests were conducted with the automated rotary-wiping system described in Section 5.1 "Computer-Controlled Linear- and Rotary-Wiping Devices" and in Attachment A, Volume II of this report.

All of the tests were run at room temperature and ambient relative humidity. Prior to the start of a test, the identification number, material type, and dimensions of the test coupon to be used as a substrate in the test were recorded. Then the connection of the control Personal Computer (PC) to the stepper motor driver of the rotary-wiping system was visually confirmed. The HyperTerminal terminal emulation/serial communications program on the control PC was then opened, and the appropriate rotary-wiping program command was selected. The operation of the rotary-wiping system (hardware and software) was then verified by running a test program.

(1) Attaching the wipe.

- The rotary-wiping mandrel (Figure 6) was removed from the rotary-wiping test apparatus.

- A pre-cut 4.5 x 4.5 in. swatch of the wiping material to be evaluated was fastened tautly across the bottom surface of the rotary-wiping mandrel and fastened to the mandrel with a stainless steel hose clamp, as shown in Figure 7

Figure 6. Photograph of rotary-wiping mandrel.

Figure 7. Photographs of activated carbon fabric mounted on rotary-wiping mandrel.

(2) Mounting the coupons.

- The test coupon/panel, with any necessary spacers, was then mounted in the appropriate baseplate template for the chosen test, as shown in Figure 8.

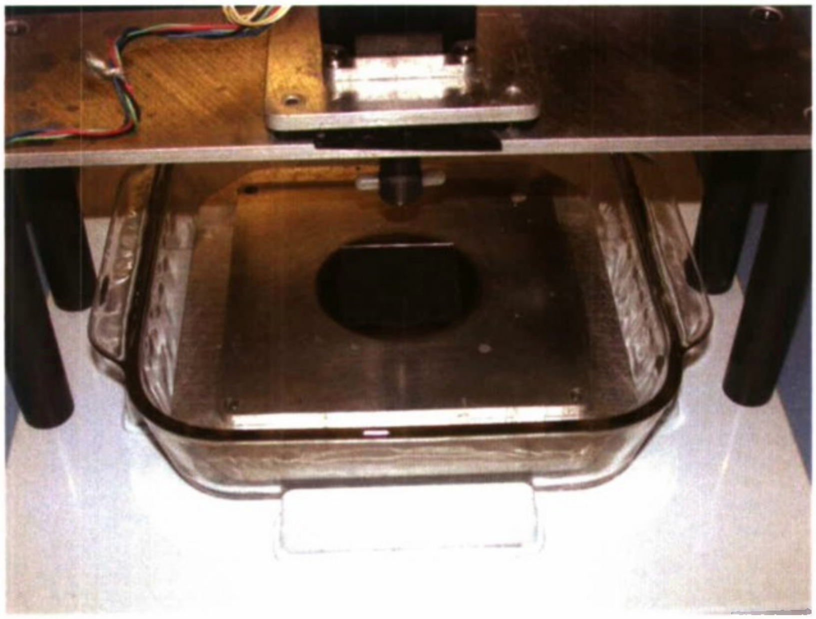


Figure 8. Photograph of CARC-painted panel, mounted in baseplate of rotary-wiping test apparatus.

- As discussed in Section 5.1 "Computer-Controlled Linear- and Rotary-Wiping Devices", two different baseplates were used in the automated rotary-wiping tests. One baseplate had a 1.5 in. square cutout for mounting a 1.5 x 1.5 in. square, 0.25 in. thick aluminum coupon. One baseplate had a 2.0 in. square cutout for mounting a 2 x 2 in. square, 0.125 in. thick, CARC-painted stainless steel panel, alkyd-painted stainless steel panels, polycarbonate coupon, or polyethylene coupon.

- Because of minor thickness differences in the 2 x 2 in. square, 0.125 in. thick test coupons, custom-fabricated 2 x 2 in. square, 3/32 in. thick aluminum shims, augmented with electrical tape for added thickness as needed, were used in these tests to make the surface of each test sample flush with the wiping surface of the baseplate of the wiping apparatus.

- In the tests with the nylon webbing, a 2 in. square swatch of the webbing was mounted on an aluminum test coupon, with the edges of the nylon swatch extending beyond each of the four edges of the aluminum test coupon. The extended edges of the nylon webbing were folded down around the edges of the aluminum test coupon. The aluminum coupon was pushed up through the underside of the template opening of the baseplate until the surface of the nylon webbing was flush with the upper (wiping) surface of the aluminum baseplate.

(3) Applying the contaminant.

All of the work with chemical agents under this test program was conducted in U.S. Army-approved chemical fume hoods in SRI's Toxic Agent Facility, in full compliance with all of the safety, security, surety, and personnel reliability requirements of SRI's Bailment Agreement DAAD13-00-H-0009 with the U.S. Army.

- After the test coupon was mounted in the baseplate of the rotary-wiping test apparatus, a 1 dram vial, containing approximately 1 mL of the agent to be used in the tests, was retrieved from the agent storage vault of the Toxic Agent Facility and transported to the chemical fume hood in which the wipe tests were being conducted.

- The upper surface of the test panel mounted in the rotary-wiping test apparatus was then uniformly contaminated with CA droplets using a microliter syringe or a micropipettor.

- In the initial HD tests with aluminum test panels, each aluminum panel was contaminated with 10 mg of neat HD, corresponding to a HD contamination density of about 7 g/m^2. In all of the remaining tests with aluminum and the other test surfaces, the agent contamination density was either 10 g/m^2 (the standard outdoor threat contamination density) or 1 g/m^2 (the standard indoor threat contamination density).

- The amount of each agent deposited on each type of coupon and the corresponding contamination density is summarized in the Table 4.

Table 4. Amount of agent deposited on test panels.

Test Surface Dimensions	Agent Contamination Density		
	10 g/m^2	7 g/m^2	1 g/m^2
1.5. x 1.5-in	14.5 mg	10.0 mg	1.45 mg
2.0 x 2.0-in.	26.1 mg	-	2.61 mg

- The neat agents were deposited as approximately 0.25 µL droplets from a 10 µL syringe to generate the indoor (low) threat agent contamination density, or as approximately 1.0 µL droplets from a 25 µL syringe to generate the outdoor (high) threat agent contamination density. Thickened GD was deposited as approximately 2 µL droplets from a micropipettor. The agent was generally deposited over the center 1 in. square of each test coupon.

(4) Initiating the wiping sequence.

- At this point in the test procedure, rotary wiping could be initiated with the dry wipe that had been attached to the rotary-wiping mandrel, or the wipe could be moistened with a solvent just prior to the initiation of the rotary wiping.

In the tests in which solvent-moistened wipes were used, the wipe that had been preattached to the rotary-wiping mandrel was moistened with solvent (either HFE-7200, HFE-71IPA, or

IPA). The solvent was sprayed initially from a pressurized aerosol can of HFE-7200 (Microcare HFE-7200) and then, after the small supply of aerosol cans were exhausted, it was sprayed from a manual hand-pump pressurized cylinder of HFE-7200, HFE-71IPA, or IPA (Misto® Olive Oil Sprayer).

The spraying procedure with the aerosol can of HFE-7200 (shown in Figure 9.) consisted of spraying the exposed bottom surface of the mandrel-mounted wipe in a single clockwise rotation, over a period of about 2 s, and from a distance of about 3 in., until all of the exposed wipe surface was moistened ("wet") with solvent (but not dripping), as determined by visual observation.

With this spraying procedure, as described in Appendix A, the measured weight of HFE-7200 on a mandrel-mounted, HFE-7200 moistened, 4.5 x 4.5 in. swatch of each of three wipe materials evaluated in this study, is shown in Table 5.

Table 5. Three wipe materials evaluated.

Material	Weight
Scotch-Brite™ 2001	7.1 ± 0.8 g
KoTHmex AW 101 Activated Carbon Fabric	4.6 ± 0.4 g
KoTHmex AM 1132-activated Carbon Felt	6.9 ± 0.5 g

The retained weight of HFE-7200 on the activated carbon fabric is lower than the retained weight on each of the other two materials, because of the weight and open weave of the fabric.

Before the start of a test, 85 mL of solvent was added to the the Misto® Olive Oil Sprayer (shown in Figure 10) from a graduated cylinder. The sprayer was then pressurized with 10 hand pumps. In the rotary-wiping tests, the mounted wipe swatch was sprayed from a distance of about 2 in. in two sequential clockwise rotations, over a period of about 5 s. Each wipe was moistened to the point of observing a visual coloration difference (as in the spraying from the Microcare pressurized aerosol can), but not enough for the wipes to drip. The measured weight of HFE-7200 that was retained by the sprayed wipes was not determined.

In the linear-wiping tests, the mounted wipe swatch was sprayed twice in a clockwise manner, from a distance of about 2 in., following the rectangular shape of the surface of the linear wipe mandrel.

Figure 9. Photograph of 3M Microcare HFE-7200 aerosol can.

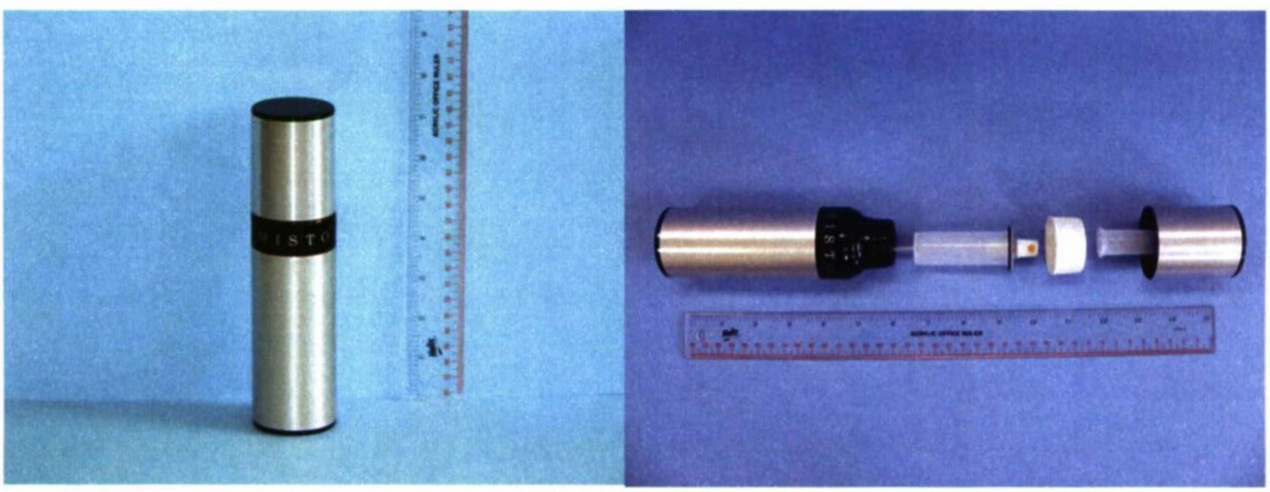


Figure 10. Photographs of assembled and disassembled Misto® olive oil sprayer.

After the test coupon was mounted in the baseplate of the rotary-wiping test apparatus, and the surface of the coupon was contaminated with agent, the wiping mandrel with a preattached wipe (dry in some tests or solvent moistened in other tests) was placed on top of the agent-contaminated surface so that the turning pin on the shaft of the stepper motor was positioned in the slotted shaft of the wiping mandrel. The selected rotary-wiping command was then entered into the HyperTerminal™ serial communications program on the control PC, initiating the rotary-wiping procedure.

In many tests, multiple iterations of a given wiping command were used (e.g., three iterations of the G330 command, designated as 3 x G330). In these tests, the given wiping command was re-entered through the PC immediately after each wiping iteration was completed.

Both single and multiple wipe sequences were used in various tests during the study:

- Dry: In each dry-wipe test, a single wipe sequence with a dry wipe was used.
- Wet: In each wet-wipe test, a wipe moistened with HFE-7200 or other solvent was used for each wipe sequence.
- Dry/Dry: In each dry/dry test, two wipe sequences were used, each with a dry wipe.
- Wet/Dry: In each wet/dry test, two wipe sequences were employed—one sequence using a wipe moistened with a solvent (either HFE-7200 or HFE-71 IPA), followed immediately by a second wipe sequence using a dry wipe.
- Wet/Wet: In each wet/wet test, two wipe sequences were employed—the first sequence using a wipe moistened with HFE-7200, followed immediately by a second wipe sequence using a wipe moistened with HFE-7200.
- Wet/Wet/Dry: In each wet/wet/dry sequence, three wipe sequences were employed—the first sequence using a wipe moistened with HFE-7200, followed immediately by a second wipe sequence using a wipe moistened with HFE-7200, followed immediately by a third wipe sequence using a dry wipe.

In the tests with multiple wipe sequences, after the completion of each wipe sequence, the wiping mandrel was immediately replaced with a new wiping mandrel with a preattached dry or wet wipe and another wipe test sequence was initiated from the control PC.

In three rotary HD tests on CARC-painted stainless steel panels, the agent contaminated test surface was sprayed with HFE-7200 from a Misto® Olive Oil Sprayer to lightly wet the agent-contaminated surface with solvent before the initiation of a single wipe sequence with a dry wipe or a wipe moistened with HFE-7200.

After the wiping procedure was complete, the wiped test coupon was removed from the rotary-wiping test apparatus and analyzed for residual agent. The sampling and analysis procedures for determining the post-test amount of residual agent on the test surface are described in Section 6.5.

6.3 Automated Rotary-Wiping Procedures for Sorbent Powder Decontaminant

The procedures for the automated rotary-wiping tests with M295/M100 sorbent powder and with MgO nanoparticle particle powder were nearly identical to the procedures used in the automated rotary-wiping tests with dry or solvent-moistened wipe materials described in Section 6.2. The difference between the procedures was the step involving decontaminant powder deposited onto the upper surface of the test panel after the contamination of the surface with CA agent, and the subsequent removal of the powder from the decontaminated surface after the test.

Prior to the start of a test, a predetermined amount of sorbent powder or nanoparticle powder was weighed out on an analytical balance directly into a glass screw top vial.

The test substrate/panel was then mounted in the automated rotary wipe test apparatus, an appropriate wiping material was attached to the rotary wiping mandrel, the PC connection to the rotary-wiping stepper motor was checked and verified, and the upper surface of the test coupon was contaminated with CA agent.

Immediately after the agent contamination of the exposed surface of the test panel, the decontaminant powder was uniformly deposited over the contaminated surface. This was initially accomplished by positioning a stainless steel screen holder over the test coupon so that the screen was directly above the coupon. The powder from the glass vial was then poured onto the surface of the screen, being careful to distribute the powder as evenly as possible over the area of the screen directly above the coupon. Then a flux brush, with bristles trimmed to approximately 3/16 in., was used to brush any residual powder through the screen. The screen was then removed and the rotary wiping procedure was initiated.

The screen assembly, however, was found to be too cumbersome and time-consuming for the deposition of the decontaminant powder. Therefore, in most of the tests, the decontaminant powder was manually deposited onto the contaminated surface of the test panel directly from the vial of powder. The same technician (the SRI Agent Handler) deposited the powder on the contaminated test surface in a careful, uniform, and reproducible manner in all of the tests.

After the wiping sequence was completed, and the wiping apparatus was disassembled and removed, a glass pipette connected to a vacuum (with filter trap) was used in conjunction with a trimmed flux brush to remove the residual contaminated powder from the surface of the test coupon.

6.4 Automated Linear Wiping for Dry and Solvent Moistened Wipes

The automated linear-wiping tests were conducted with the automated linear-wiping system, described in Section 5.1 and in Attachment A, Volume II of this report. Linear-wiping tests were conducted with HD on aluminum, CARC, alkyd, polyethylene, and polycarbonate test panels/substrates. Linear-wiping tests were not conducted on nylon webbing.

All of the tests were run at room temperature and ambient relative humidity. The identification number, material type, and dimensions of the test coupon to be used as a substrate in the test were recorded before the test was started. Then the connection of the control PC to the stepper motor driver of the linear-wiping system was visually confirmed. The appropriate rotary-wiping program command was selected using the HyperTerminal terminal emulation/serial communications program on the control PC. The operation of the linear wiping system (hardware and software) verified by running a test program, for example, G0.

A photograph of the linear-wiping test apparatus configured as initially received, with three aluminum test coupons for the preliminary linear-wiping tests, is shown below in Figure 11.

(1) Mounting the coupons.

- Three 1.5 x 1.5 in. square aluminum coupons were placed in the cut-out slots in the aluminum baseplate of the linear-wiping device, as shown in Figure 11.
- A 2.0 x 2.0 in. test coupon, the test coupon/panel, with any necessary spacers, was mounted in the cutout slot in the appropriate baseplate template for the chosen test, as shown in Figure 12.

- As diseussed in Seetion 5.1, two different baseplates were used in the automated rotary-wiping tests—one baseplate with three 1.5 in. square eutouts for mounting 1.5 x 1.5 x 0.25 in square aluminum eoupons, and one baseplate with a single 2.0 in. square eutout for mounting a 2 x 2 x 0.125 in. CARC-painted stainless steel panel, alkyd-painted stainless steel panels, polycarbonate eoupon, or polyethylene eoupon.

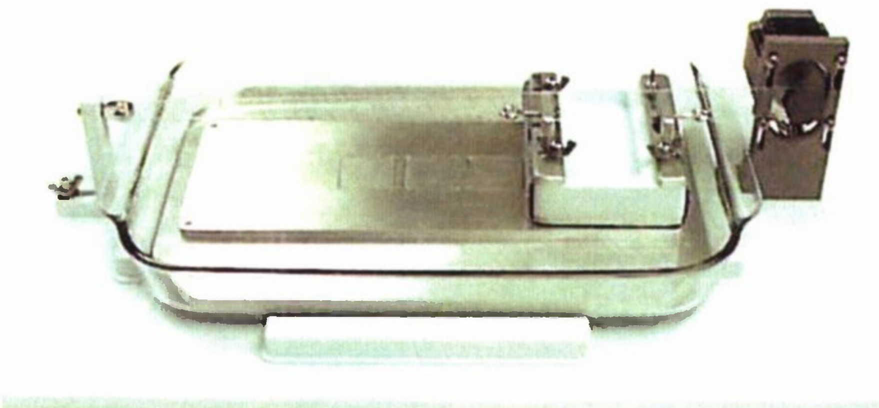


Figure 11. Photograph of linear-wiping test apparatus using original baseplate with three aluminum test coupons.

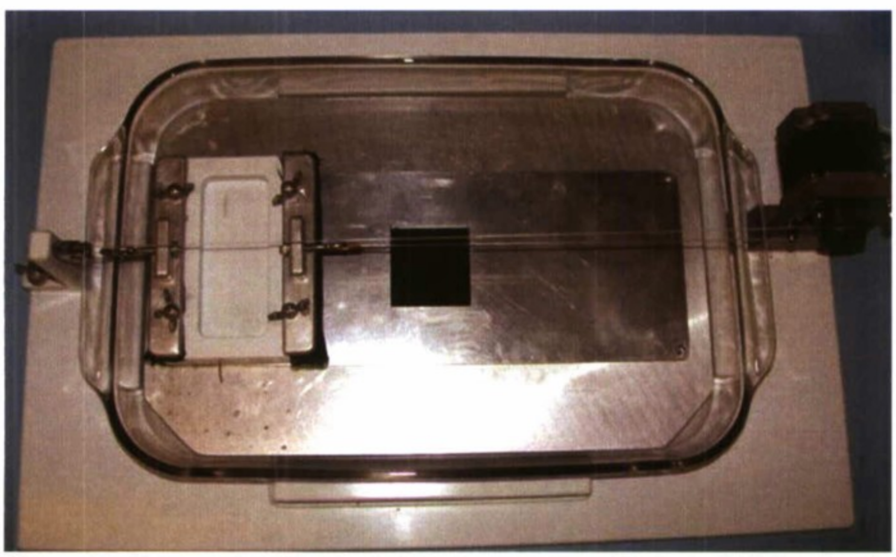


Figure 12. Photograph of linear-wiping test apparatus with single CARC-painted test coupon.

- Beeause of minor thiekness variabilities in the 2 x 2 in. square x 0.125 in. thiek test eoupons, thin eustom-fabrieated 2 x 2 in. square x 3/32 in. thiek aluminum shims, augmented with eleetrieal tape for added thiekness as needed, were used in these tests. The shims were needed to make the surfaee of eaeh test sample flush with the wiping surfaee of the baseplate of the wiping apparatus.

(2) Attaching the wipe.

- The linear wiping block was then removed from the linear wipe test apparatus and a pre-cut 8 x 5 in. swatch of wiping material was fastened tautly across the bottom surface of the rotary-wiping mandrel. The wipe was then attached to the block by loosening the four wing nuts on the block, placing the ends of the wipe swatch under the metal bar on the block, and tightening the wing nuts. A photograph of an activated carbon fiber wipe material mounted on the linear wiping block is shown in Figure 13 below.

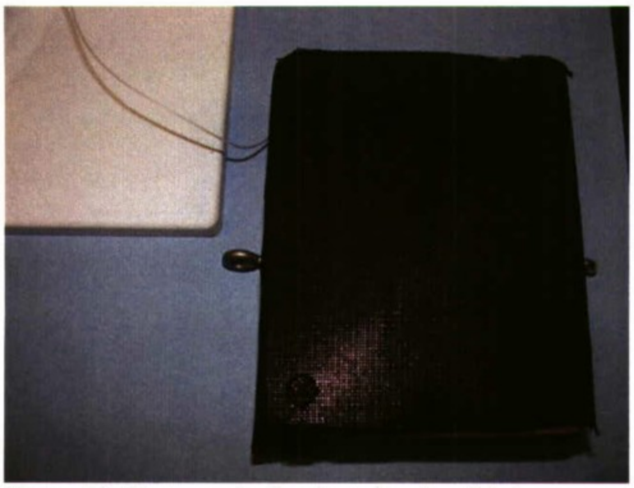


Figure 13. Photograph of activated carbon fabric mounted on linear wiping mandrel.

(3) Applying the contaminant.

- After the test coupon was mounted in the baseplate of the linear wipe test apparatus, and the wiping material was attached to the wiping block, a 1 dram vial containing approximately 1 mL of the CA agent to be used in the tests was retrieved and transported to the chemical fume hood.

- The upper surface of the designated test coupon was then uniformly contaminated with HD droplets using a microliter syringe (either a 10 μL syringe or a 25 μL syringe). The HD contamination density was either 10 g/m^2 or 1 g/m^2 (1.45 mg on the 1.5 x 1.4 in. aluminum test coupons and 2.61 mg on the 2.0 x 2.0 in. test coupons).

(4) Initiating the wiping sequence.

- Dry Wipes: After agent contamination, the wiping mandrel was then positioned at the far left side of the aluminum baseplate or just to the left of the leftmost aluminum test coupon (in the tests with three coupons). The wiping sequence, with dry wipes, was initiated.

- Wet Wipes: In the tests using solvent-moistened wipes, the surface of the block-mounted wipe swatch was sprayed with solvent from a Misto® Olive Oil Sprayer. The spraying procedure consisted of adding 85 mL of solvent to the sprayer from a graduated cylinder (conducted prior to the start of a test). The sprayer was pressurized with 10 hand pumps. The mounted wipe swatch was then sprayed twice from a distance of about 2 in., in a clockwise manner, following the rectangular surface of the linear wipe mandrel (a total spraying time of about 5 or 6 s). Each wipe was moistened to the point of observing a visual coloration difference, but not enough for the wipes to drip.

- The linear wipe block with attached wiping material (either solvent-moistened or dry) was then placed down on the far left side of the aluminum baseplate. The nylon fishing line was then attached to the two eyelets on the opposite sides of the wiping mandrel, routed through the pulley, wrapped around the motor shaft three times, and tensioned by loosening the wing nut on the pulley, moving the pulley away from the motor until the line is taut, and tightening the wing nut.

- The selected rotary-wiping command was then entered into the HyperTerminal™ serial communications program, and the linear wipe procedure was initiated.

- In a few tests, multiple iterations of a given wiping command were used (e.g., four iterations of the G240 command, designated as 4 x G240). In these tests, the given wiping command was repeated immediately after each wiping iteration.

One iteration of the G240 linear-wiping program consisted of six sequential linear wipe passes over the test coupons: (1) a left to right pass, (2) a right to left return pass, (3) a second left to right pass, (4) a second right to left return pass, (5) a third left to right pass, and (6) a third right to left return pass. The duration of each pass was 2.0 s, so the total wiping time was 12.0 s.

In several HD linear-wiping tests, the agent-contaminated test surface was sprayed with HFE-7200 from a Misto® Olive Oil Sprayer to lightly wet the agent-contaminated surface with solvent before the initiation of a single wipe sequence with a dry wipe or a wipe moistened with HFE-7200.

After the wiping procedure was complete, the wiped test coupon was removed from the rotary-wiping test apparatus and analyzed for residual agent. The sampling and analysis procedures for determining the post-test amount of residual agent on the test surface are described in Section 6.5.

6.5 Procedures for Determination of Residual Agent on Post-Test Coupons

Several different sampling and analysis procedures were used throughout the experimental test program for determining the amount of agent remaining following the decontamination process on and in a test surface after the wiping procedures:

- Static vapor off-gassing

- Near Real Time Vapor Off-Gas Monitoring with MINICAMS and ACAMS

- DAAMS Sampling and Analysis

- Solvent Extraction and GC Analysis

6.5.1 Static Vapor Off-Gas Monitoring

Only a single preliminary test using static vapor off-gas monitoring (bag sampling) was conducted during the study. It was used in the first wiping test, involving HD contamination, and the wiping of an aluminum control surface, followed by vapor off-gas monitoring. It is described briefly here for completeness.

The decontaminated (wiped) stainless steel disk was placed in a polyethylene bag with a total volume of about 30 L of air, at ambient temperature and relative humidity. The bag was sealed and allowed to sit undisturbed for 2 h. The headspace in the bag was sampled with a MINICAMS, configured and calibrated to detect HD vapor at a concentration of less than 0.5 TWA, at roughly 1 h intervals over about a 3 h time frame.

Select MINICAMS parameters are summarized in the Table 6 below:

Table 6. HD MINICAMS-FPD method parameters for static vapor off-gas monitoring.

Parameter	HD
Column	15 meter DB-1
PCT Sorbent	Tenax-TA
FPD Filter	Sulfur
Low Column Temp, °C	50
High Column Temp, °C	250
Ramping Rate, °C/min	334
Column Time, s	101
Low PCT Temp, °C	40
High PCT Temp, °C	250
FPD Temperature, °C	150
Sample Rate, mL/min	250
Sample Time, min	4
Purge Time, s	130
Total Cycle Time, s	370
Retention Time, s	112
H2 Pressure, psig	35
Air Pressure, psig	35
Carrier Gas	Nitrogen
N2 Pressure, psig	40
PMT Voltage, v	950

6.5.2 Time-Resolved Near Real Time (NRT) Vapor Off-Gas Monitoring with MINICAMS

Time-resolved MINICAMS NRT monitoring of post-wipe test coupons was conducted primarily in wiping tests with HD-contaminated and wiped aluminum test coupons. In the MINICAMS time-resolved NRT sampling and analysis, the wiped test coupon was placed in a 16 oz. glass sampling jar. The jar was fitted with stainless steel air inlet and outlet tube fittings in the Teflon-lined cap of the jar. Room air was sampled at timed intervals into and through the jar into a MINICAMS through approximately 6 ft of unheated 0.125 in. OD Teflon TFE tubing. Photographs of a glass sampling jar containing an aluminum test coupon and of the MINICAMS used to sample the effluent air from the jar are shown in Figure 14. The collected samples were analyzed directly by the MINICAMS. The air flowing across the wiped aluminum test coupon in each jar was sampled and analyzed for residual agent vapor for up to 2 h.

In each test, the concentration of off-gassing HD (in units of TWA) and the HD off-gassing rate (in units of ng/min) were plotted as a function of time. Typical HD vapor off-gas curves are shown in Figure 15. The sampling and analysis data from a typical MINICAMS vapor off-gassing test, from which the vapor off-gas curves were generated, are shown in Table 7.

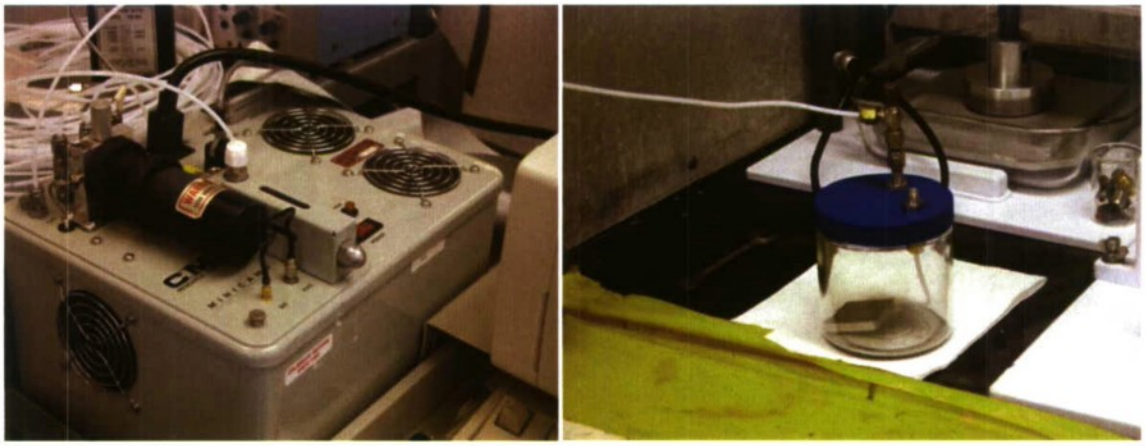


Figure 14. Photograph of MINICAMS (left) and sampling jar (right).

In Table 7, the MINICAMS HD response (peak height in nA) is tabulated for each MINICAMS cycle, along with the MINICAMS time of day output and the calculated elapsed time from the start of sampling. The total cycle time of each MINICAMS cycle was 430 s, or approximately 7.2 min. Thus, the elapsed time interval in each line item entry was incremented by 430 s from the previous entry.

Prior to the start of a test or series of tests, a multipoint calibration of the MINICAMS was performed using standard solutions of HD in IPA. A linear regression analysis of the calibration data was conducted to correlate the HD peak response in each MINICAMS cycle to a known amount of HD. From the calculated amount of HD determined in each MINICAMS cycle, the sample volume, and the TWA value for HD (3 ng/L), the concentration of HD in each MINICAMS cycle was calculated and listed. From the calculated amount of HD detected in each cycle and the MINICAMS sample time (5 min), the off-gassing rate of HD (in units of ng/min) was calculated and listed. Two vapor off-gas curves were generated in each test—a plot of HD concentration (TWA) vs. time and a plot of HD off-gassing rate (ng/min) vs. time.

The cumulative amount of HD as a function of elapsed time was then calculated through each sampling interval by numerical integration (Simpson's Rule) and was tabulated in the rightmost column of each line of the tabulated data. The calculated cumulative amount of HD at the end of the total sampling period (typically 120 min) was reported as the amount of residual HD recovered from the wiped test surface.

The decontamination efficacy (DE) of the wiping procedure was then calculated from the following equation:

$$\text{DE} = \frac{(\text{Amount of Agent Initially Deposited} - \text{Amount of Residual Agent})}{(\text{Amount of Agent Initially Deposited})} \times 100\% \qquad \text{Equation 1}$$

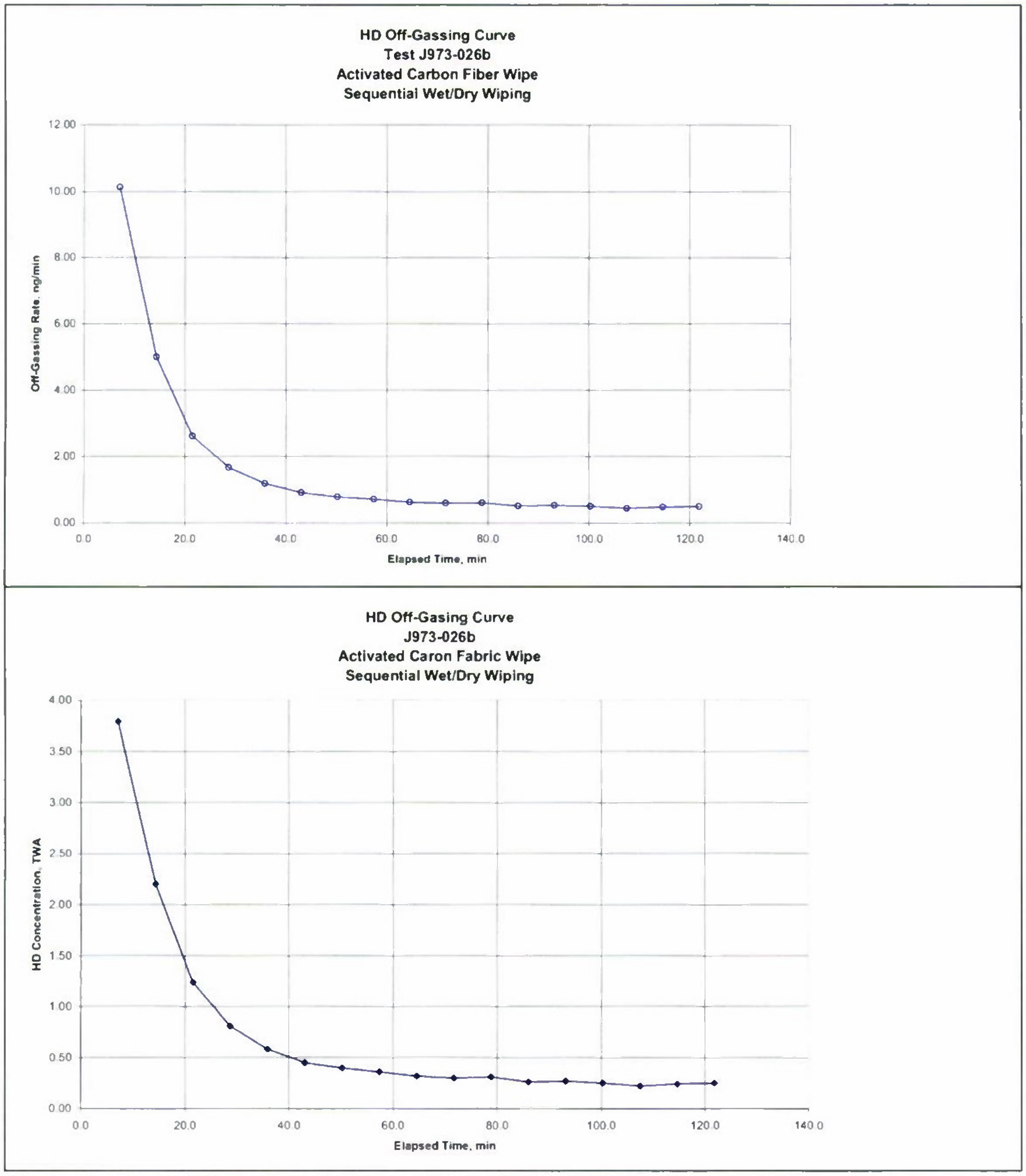


Figure 15. Typical HD vapor off-gas curves from Test J978-026 (B).

(NOTE: Y-axis in upper curve in units of ng/L; y-axis in lower curve in units of TWA.)

Table 7. Sampling and analysis data from a typical MINICAMS vapor off-gas test.

Test Number:	J973-026(B)							
Time	Elapsed Time min	Peak Height nA	Calc'd ng	Sample Volume L	Conc'n ng/L	Calc'd TWA	Off-Gassing Rate ng/min	Cumulative Off-Gassing ng
1414	7.2	1366.2	50.66	2.00	25.33	8.44	10.13	
1422	14.3	381.4	25.00	2.00	12.50	4.17	5.00	54.22
1429	21.5	117.9	13.06	2.00	6.53	2.18	2.61	81.50
1436	28.7	52.6	8.35	2.00	4.18	1.39	1.67	96.84
1443	35.8	28.1	5.90	2.00	2.95	0.98	1.18	107.06
1450	43.0	17.5	4.54	2.00	2.27	0.76	0.91	114.55
1458	50.2	13.5	3.94	2.00	1.97	0.66	0.79	120.62
1505	57.3	11.3	3.57	2.00	1.78	0.59	0.71	126.00
1512	64.5	8.8	3.11	2.00	1.55	0.52	0.62	130.78
1519	71.7	8.2	2.99	2.00	1.49	0.50	0.60	135.15
1526	78.8	8.3	3.01	2.00	1.50	0.50	0.60	139.44
1533	86.0	6.1	2.54	2.00	1.27	0.42	0.51	143.41
1541	93.2	6.4	2.60	2.00	1.30	0.43	0.52	147.10
1548	100.3	5.9	2.49	2.00	1.24	0.41	0.50	150.75
1555	107.5	4.5	2.14	2.00	1.07	0.36	0.43	154.06
1602	114.7	5.2	2.32	2.00	1.16	0.39	0.46	157.26
1609	121.8	5.6	2.42	2.00	1.21	0.40	0.48	160.66

MINICAMS Calibration Data

Linearization Factor: 1.807

Amount HD ng	Peak Area nA	Linearized Area	Lin Reg Peak Area	Curve Fit Deviation %
0.00	0	0	0.00	
1.580	3.04	1.85	1.70	-9.1%
2.95	5.74	2.63	3.17	16.9%
5.91	20.90	5.38	6.34	15.2%
11.80	83.00	11.54	12.66	8.9%
23.60	365.00	26.18	25.32	-3.4%

Linear Regression Analysis

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.995988
R Square	0.991992
Adjusted R Sq	0.741992
Standard Error	0.900573
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	1	401.8526	401.85265	495.483	0.000199
Residual	4	3.244126	0.8110315		
Total	5	405.0968			

	Coefficients	*tandard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	1.072901	0.033054	32.459234	5.4E-06	0.981128	1.164673	0.981128424	1.164672858

In the agent tests discussed in this volume of the report, decontamination efficacy and wipe efficiency are identical for the tests with non-absorptive test surfaces, i.e., stainless steel and aluminum. However, in the tests with agent-absorptive test surfaces (CARC- and alkyd-painted panels, nylon webbing, polycarbonate, and high-density polyethylene), the agent vapor off-gas monitoring and solvent extraction techniques used in the tests determine the amount of residual agent remaining "in" (at least to some extent) as well as "on" the contaminated and wiped surface of each test coupon. Thus, for the agent-absorptive surfaces, decontamination efficacy may not be identical to wipe efficiency, depending on the extent of agent absorption into the surface. All of the agent-wipe test results in this volume of the report are reported in terms of decontamination efficacy.

The MINICAMS-FPD instrument and HD method parameters are summarized in Table 8 below.

Table 8. HD MINICAMS-FPD method parameters.

Parameter	HD
Column	15 meter DB-1
PCT Sorbent	Tenax-TA
FPD Filter	Sulfur
Low Column Temp, °C	50
High Column Temp, °C	200
Ramping Rate, °C/min	334
Column Time, s	101
Low PCT Temp, °C	40
High PCT Temp, °C	250
FPD Temperature, °C	150
Sample Rate, mL/min	400
Sample Time, min	5
Purge Time, s	130
Total Cycle Time, s	430
Retention Time, s	112
H_2 Pressure, psig	35
Air Pressure, psig	35
Carrier Gas	Helium
He Pressure, psig	40
PMT Voltage, v	900

6.5.3 Near Real-Time Vapor Off-Gas Monitoring Using ACAMS

Time-resolved Automatic Continuous Air-Monitoring System (ACAMS) NRT monitoring of post-wipe test coupons was conducted in preliminary tests with TGD-contaminated and wiped aluminum test coupons. In the ACAMS time-resolved NRT sampling and analysis, the wiped test coupon was placed in a glass sampling jar with air inlet and outlet fittings in the cap of the jar. Room air was sampled at timed intervals into and through the jar into an ACAMS. Refer to Table 9 for the method parameters. The collected samples were analyzed directly by the ACAMS. Each jar was sampled and analyzed for residual agent vapor for up to 2 h. In each test, the concentration of off-gassing GD (in units of ng/min and in units of TWA) was plotted as a function time.

Table 9. HD ACAMS-FPD method parameters.

Parameter	GD
Column	15 meter DB-1
PCT Sorbent	Tenax-TA
FPD Filter	Sulfur
Sample Rate, mL/min	200
Sample Time, min	3.5
Total Cycle Time, s	330
Sample Volume, mL	700

6.5.4 Depot Area Air-Monitoring System (DAAMS) Sampling and Analysis

DAAMS sampling and analysis were used in HD-wiping tests only, primarily with aluminum and CARC test coupons. Refer to Table 10 for method parameters. In the DAAMS sampling and analysis, after the completion of the wiping procedure, the wiped test coupon was placed in a 16 oz. glass sampling jar that was fitted with stainless steel air inlet and outlet Swagelok fittings in the Teflon-lined cap of the jar. Room air was pumped into and through the jar and then through a 3 mm OD Tenax TA DAAMS transfer tube. In about one-third of the tests, a DAAMS sample flow rate of 50 mL/min, and a sample time of 120 min (for a total sample volume of 6.0 L) was used to determine the total amount of residual agent that could be recovered from the wiped test surface by vapor off-gas analysis.

In the remainder of the tests with DAAMS sampling and analysis, room air was pumped into and through the jar then through a 3 mm OD Tenax TA DAAMS transfer tube at a flow rate of 200 mL/min for 15 min. Then the DAAMS tube was replaced with a second tube that sampled at the same flow rate for another 15 min, then by a third tube that sampled for another 30 min, a fourth tube that sampled for another 30 min, and a fifth tube that sampled for a final 30 min. A total of five DAAMS tubes were used to sample sequentially, at 200 mL/min for a total of 120 min (a total sample volume of 24 L). In a few of the tests, the DAAMS sample flow rate was decreased from 200 to 50 mL/min, and the DAAMS sample times were decreased from 15 and 30 min to 15 and 30 s, respectively, because of large amounts of off-gassed HD collected in earlier tests.

The DAAMS transfer tubes were then thermally desorbed into an HP 5890 Series II GC equipped with a DAAMS injection port, a flame ionization detector, and an HP 3396A Series II integrator.

Prior to the tests, the GC was calibrated over a range of 8 to 984 ng HD. The calibration curve was linear over the calibration range with a correlation coefficient of 0.999. The total amount of HD collected on, and desorbed from the DAAMS tube (in ng), was determined directly from GC response of the desorbed DAAMS sample and the HD calibration curve. This value is a measure of the residual amount of HD that remained on the test surface after the completion of the wiping cycles. The decontamination efficacy of the wiping protocol is calculated from the residual amount of HD remaining on the test surface and the known amount of HD (10 mg) initially deposited on the test surface.

Table 10. HD DAAMS-GC/FPD method parameters.

Parameter	HD-DAAMS-GC/FID
Sorbent	Tenax-TA
Sample Rate, mL/min	50 - 200 mL/min
Sample Time, min	15 - 120 (varied) *1
Sample Volume (L)	x - 6 varied *2
Column	15-m DB-210
Carrier Gas	Helium
Carrier Pressure, psig	75
Injection Port Temp. °C	225
Init. Column Temp., °C	80
Initial Hold Time (min)	0.5
Ramping Rate, °C/min	40
Final Column Temp, °C	140
Final Hold Time (min)	2
Detector	FID
Detector Temperature, °C	300
H_2 Pressure, psig	55
Air Pressure, psig	85
HD Retention Time, min	~1.30
GD Retention Time, min	NA
VX Retention time, min	NA
FPD Filter	N/A

6.5.5 Solvent Extraction and GC Analysis

In the majority of the agent-wiping tests conducted, the amount of post-wipe residual agent remaining on the surface of a test coupon was determined by solvent extraction and GC analysis.

After the completion of the wiping procedure, each wiped test coupon was removed from the wipe test apparatus and placed into a glass sampling jar containing a pre-measured volume of extraction solvent—isopropyl alcohol (IPA) in most of the tests, hexane in a couple of HD tests. The 1.5 x 1.5 in. square aluminum and nylon test coupons were placed into a 4 oz. sampling jar containing 25 mL of extraction solvent. The 2 x 2 in. square CARC, alkyl, polyethylene, or polycarbonate test coupons were placed in an 8 oz. sampling jar containing 50 mL of extraction solvent. Before the start of a test, the appropriate volume of extraction solvent was added to each sampling jar using a variable-volume Brinkmann Digital Dispensette connected to a bottle of reagent or pesticide grade solvent.

Each test coupon was allowed to sit immersed in the extraction solvent at room temperature, with occasional swirling, for a minimum of 2 h. At the end of the extraction period, an aliquot of the extraction solvent was removed from the sample jar, volumetrically diluted if required, transferred to a glass autosampler vial, and analyzed for agent on an HP 5890 Series II GC equipped with an autosampler, a flame photometric detector, and an HP 3396A Series II integrator. HD analyses were conducted with a sulfur interference filter in the FPD; GD and VX analyses were conducted with a phosphorus interference filter.

The GC was calibrated over a nominal range of 0.5–20 ng for HD, 0.9–14 ng for VX, and 0.9–14 ng for GD. The GC/FPD parameters used in the analyses of the HD, TGD, and VX solvent extracts are shown in the Table 11 below.

Table 11. GC/FPD parameters used in the analyses of the HD, TGD, and VX solvent extracts.

Parameter	HD/TGD/VX-GC/FPD
Column	15-m DB-210
Carrier Gas	Helium
Carrier Pressure, psig	75
Injection Port Temp. °C	275
Init. Column Temp., °C	80
Initial Hold Time (min)	0.5
Ramping Rate, °C/min	40
Final Column Temp, °C	140
Final Hold Time (min)	0.5
HD Injection Volume, µL	2 to 5 (variable)
VX Injection Volume, µL	3
TGD Injection Volume, µL	3
Detector	FPD
Detector Temperature, °C	250
H_2 Pressure, psig	45
Air Pressure, psig	80
HD Retention Time, min	~1.230
GD Retention Time, min	~1.3
VX Retention time, min	~ 3.0
FPD Filter	Phosphorus – TGD & VX Sulfur – HD

6.5.6 Wipe Contact Times

The total wiping contact times used in the various rotary and linear wiping tests are summarized in Table 12 below.

Table 12. Wiping contact times of rotary and linear wiping programs.

Rotary-Wiping Sequence	Contact Time (s)	Linear Wipe Sequence (s)	Contact Time (s)
1 x G300	8	1 x G0	0.5
1 x G330	16	1 x G180	2
2 x G330	32	1 x G240	12
3 x G330	48	4 x G240	48

6.6 Temperature and Relative Humidity Measurement

All of the chemical-agent wipe tests in this study were conducted in a chemical fume hood at ambient temperature and relative humidity. The ambient temperature and relative humidity (RH) in the fume hood were measured with a small Fisherbrand Model 11-661-13 digital hygrometer/thermometer. The digital temperature/RH meter was located in the front corner of a Pyrex baking dish located on the floor of the hood. The Pyrex dish served as the agent spill tray and as the holding tray for the microliter syringes and other agent-related items that were used in the wipe tests.

With a few exceptions, the ambient temperature and relative humidity was noted and recorded once during each test. The measured temperature and relative humidity of each test are listed in the next section of this report.

7. TEST RESULTS AND DISCUSSIONS

A comprehensive listing of the entire wipe tests, with the associated test parameters for each test that were conducted with agents during the study, is given in Table 13 and Table 14.

The wiping tests in Table 13 and Table 14 are listed in chronological order. Each line item entry in the table includes the following information:

- Test number (keyed to SRI notebook and page number)
- Wiping material
- Test panel/surface
- Agent (HD, TGD, or VX)
- Agent Lot
- Amount of agent deposited on test surface
- Solvent or decontaminant powder applied to contaminated surface
- Method of dispensing solvent (typically MicroCare aerosol can or Misto® Olive Oil Sprayer
- Type of wipe test (manual rotary, automated rotary, automated linear)
- Weight of wiping mandrel (rotary-wiping tests) or wiping block (linear-wiping tests)
- Wiping program used in automated tests
- Number of iterations of wiping program
- Type of wipe used in each wipe iteration [dry, wet (= solvent moistened)]
- Solvent sprayed onto contaminated test coupon or decontaminant powder applied to contaminated surface

- Sampling method for determination of residual agent
- Extraction solvent, if applicable
- Analysis method for determination of residual agent (GC/FPD, GC/FID, MINICAMS/FPD, ACAMS/FPD)
- Surface temperature of test panel
- Ambient relative humidity

The various agent-wiping tests that were conducted during the study are grouped into the following categories:

- HD Rotary Screening Tests of Potential Wiping Materials
- Developmental HD Wipe Tests with Vapor Monitoring
- HD Automated Rotary-Wiping Tests on Non-Absorptive Aluminum Surfaces
- TGD Automated Rotary-Wiping Tests on Non-Absorptive Aluminum Surfaces
- HD Automated Linear-Wiping tests on Non-Absorptive Aluminum Surfaces
- HD Automated Rotary-Wiping Tests on Absorptive Surfaces
- HD Automated Linear-Wiping tests on Absorptive Surfaces
- HD, VX, and TGD Comparative Automated Rotary-Wiping Tests

In the following sections of this report, each category of tests is described, and the test results are presented and discussed.

Table 13. Comprehensive list of wipe tests and test parameters.

Test ID (& No. of Replicates)	Wipe Material	Test Substrate	Agent	Agent Lot	Agent Deposited	Solvent or Decon	Solvent or Decon Dispenser	Type of Test
J906-008a-c	3M Scotch Brite 2011	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-008d-f	3M Scotch Brite 2011	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-014a-c	3M Scotch Brite 2011	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-014d-f	3M Scotch Brite 2011	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-026a-c	A/C Felt AM 1131	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-026d-f	A/C Felt AM 1131	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-030a-c	A/C Fabric AW 1501	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-030d-f	A/C Fabric AW 1501	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-034a-c	P&G Swiffer wipes	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-034d-f	P&G Swiffer wipes	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-038a-c	Polyester felt nonwoven	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-038d-f	Polyester felt nonwoven	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-042a-c	Pledge "Grab-It" wipes	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-042d-f	Pledge "Grab-It" wipes	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-046a-c	Teri Reinforced Wipers	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-046d-f	Teri Reinforced Wipers	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-050a-c	3M Scotch Brite 2021N	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-050d-f	3M Scotch Brite 2021N	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-054a-c	Cutex Simple Pad (non-acetone)	ss disks	HD	010503-1	10 mg	Ethyl Acetate IPA Water	-	Manual rotary
J906-059a-b	Clorox Disinfecting Wipes (Lemon Scent)	ss disks	HD	010503-1	10 mg	Aqueous IPA 1-5%	-	Manual rotary
J906-059d-f	Clorox Disinfecting Wipes (Fresh Scent)	ss disks	HD	010503-1	10 mg	Aqueous IPA 1-5%	-	Manual rotary
J906-070a-c	Bounty Paper Towels	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-070d-f	Bounty Paper Towels	ss disks	HD	010503-1	10 mg	HFE-7200	Micro-Care	Manual rotary
J906-078a-c	Lever 2000 Wipes	ss disks	HD	010503-1	10 mg	70-99% water	-	Manual rotary
J906-078d-f	Safety Equipment Cleaning Pads	ss disks	HD	010503-1	10 mg	>99% water	-	Manual rotary
J906-085a	3M Scotch Brite 2021	aluminum	HD	010503-1	10 mg	None	-	Rotary
J906-085b	3M Scotch Brite 2021	aluminum	HD	010503-1	10 mg	HFE-7200	Micro-Care	Rotary
J906-090a	3M Scotch Brite 2021	aluminum	HD	010503-1	10 mg	None	-	Rotary
J906-090b	3M Scotch Brite 2021	aluminum	HD	010503-1	10 mg	HFE-7200	Micro-Care	Rotary
J906-094a	A/C Fabric AW 1101	aluminum	HD	010503-1	10 mg	None	-	Rotary

Table 13. Comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Wipe Material	Test Substrate	Agent	Agent Lot	Agent Deposited	Solvent or Decon	Solvent or Decon Dispenser	Type of Test
J906-094b	A/C Fabric AW 1101	aluminum	HD	010503-1	10 mg	HFE-7200	Micro-Care	Rotary
J906-100a	A/C Fabric AW 1101	aluminum	HD	010503-1	10 mg	None	-	Rotary
J906-100b	A/C Fabric AW 1101	aluminum	HD	010503-1	10 mg	HFE-7200	Micro-Care	Rotary
J906-104 (3)	A/C Fabric AW 1101	aluminum	HD	010503-1	10 mg	HFE-7200	Micro-Care	Rotary
J906-106 (3)	3M Scotch Brite 2021	aluminum	HD	010503-1	10 mg	HFE-7200	Micro-Care	Rotary
J906-110 (3)	Teri Reinforced Wipers	aluminum	HD	010503-1	10 mg	HFE-7200	Micro-Care	Rotary
J906-112 (3)	A/C Felt AM 1132	aluminum	HD	010503-1	10 mg	HFE-7200	Micro-Care	Rotary
J906-130	A/C Fabric AW 1101	aluminum	TGD	012401-3	10 mg	HFE-7200	Micro-Care	Rotary
J906-134 (2)	A/C Fabric AW 1101	aluminum	TGD	012401-3	10 mg	HFE-7200	Micro-Care	Rotary
J906-138 (3)	A/C Felt AM 1132	aluminum	TGD	012401-3	10 mg	HFE-7200	Micro-Care	Rotary
J906-142 (3)	3M Scotch Brite 2021	aluminum	TGD	012401-3	10 mg	HFE-7200	Micro-Care	Rotary
J973-008 (3)	A/C Fabric AW 1101	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-012 (3)	A/C Fabric AW 1101	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-014 (3)	A/C Fabric AW 1101	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-016 (3)	A/C Fabric AW 1101	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-022 (3)	A/C Fabric AW 1101	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-026 (3)	A/C Fabric AW 1101	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-030 (3)	A/C Fabric AW 1101	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-046 (3)	A/C Fabric AW 1101	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-048 (3)	A/C Felt AM 1132	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-050 (3)	3M Scotch Brite 2021	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-052 (3)	A/C Fabric AW 1101	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-054 (3)	A/C Felt AM 1132	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-056 (3)	3M Scotch Brite 2021	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-058 (3)	A/C Felt AM 1132	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-060 (3)	3M Scotch Brite 2021	aluminum	HD	011003-1	10 mg	HFE-7200	Micro-Care	Rotary
J973-062 (3)	A/C Fabric AW 1101	aluminum	HD	011003-1	10 mg	HFE-7200	Misto	Rotary
J973-066 (3)	Wypall X70	aluminum	HD	011003-1	10 mg	HFE-7200	Misto	Rotary
J973-070 (3)	A/C Fabric AW 1101	aluminum	HD	011003-1	10 mg	HFE-71IPA	Misto	Rotary
J973-074 (3)	A/C Felt AM 1132	aluminum	HD	011003-1	10 mg	HFE-71IPA	Misto	Rotary
J973-078 (3)	3M Scotch Brite 2021	aluminum	HD	011003-1	10 mg	HFE-71IPA	Misto	Rotary
J973-082 (3)	A/C Fabric AW 1101	aluminum	HD	011003-1	10 mg	HFE-7200	Misto	Rotary
J973-088 (3)	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Rotary
J973-096 (3)	A/C Felt AM 1132	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Rotary
J973-104 (3)	3M Scotch Brite 2021	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Rotary
J973-114	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear
J973-116	A/C Felt AM 1132	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear
J973-118	3M Scotch Brite 2021	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear
J973-120	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J973-122	A/C Felt AM 1132	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J973-124	3M Scotch Brite 2021	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J973-126	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear
J973-128	A/C Felt AM 1132	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear

Table 13. Comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Wipe Material	Test Substrate	Agent	Agent Lot	Agent Deposited	Solvent or Decon	Solvent or Decon Dispenser	Type of Test
J973-130	3M Scotch Brite 2021	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear
J973-132	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J973-134	A/C Felt AM 1132	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J973-136	3M Scotch Brite 2021	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J973-140	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J973-142	A/C Felt AM 1132	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J973-144	3M Scotch Brite 2021	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J973-146	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J973-148	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear
J973-150	3M Scotch Brite 2021	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear
J973-152	A/C Felt AM 1132	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear
J973-156	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear
J1073-004	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J1073-006	3M Scotch Brite 2021	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J1073-008	A/C Felt AM 1132	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J1073-014	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear
J1073-016	3M Scotch Brite 2021	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear
J1073-018	A/C Felt AM 1132	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear
J1073-022	A/C Fabric AW 1101	aluminum	HD	011003-1	1.45 mg	None	-	Linear
J1073-026	A/C Fabric AW 1101	aluminum	HD	011003-1	1.45 mg	None	-	Linear
J1073-028	A/C Fabric AW 1101	aluminum	HD	011003-1	1.45 mg	HFE-7200	Misto	Linear
J1073-032	3M Scotch Brite 2021	aluminum	HD	011003-1	1.45 mg	None	-	Linear
J1073-034	3M Scotch Brite 2021	aluminum	HD	011003-1	1.45 mg	HFE-7200	Misto	Linear
J1073-038	A/C Felt AM 1132	aluminum	HD	011003-1	1.45 mg	None	-	Linear
J1073-040	A/C Felt AM 1132	aluminum	HD	011003-1	1.45 mg	HFE-7200	Misto	Linear
J1073-042	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J1073-044	3M Scotch Brite 2021	aluminum	HD	011003-1	14.5 mg	None	-	Linear
J1073-046	A/C Felt AM 1132	aluminum	HD	011003-1	14.5 mg	HFE-7200	Misto	Linear
J1073-048	A/C Fabric AW 1101	aluminum	HD	011003-1	1.45 mg	HFE-7200	Misto	Linear
J1073-050	A/C Fabric AW 1101	aluminum	HD	011003-1	1.45 mg	None	-	Linear
J1073-054	3M Scotch Brite 2021	aluminum	HD	011003-1	1.45 mg	None	-	Linear
J1073-056	3M Scotch Brite 2021	aluminum	HD	011003-1	1.45 mg	HFE-7200	Misto	Linear
J1073-058	A/C Felt AM 1132	aluminum	HD	011003-1	1.45 mg	None	-	Linear
J1073-060	A/C Felt AM 1132	aluminum	HD	011003-1	1.45 mg	HFE-7200	Misto	Linear
J1073-064	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	IPA	Misto	Linear
J1073-066	A/C Fabric AW 1101	aluminum	HD	011003-1	14.5 mg	IPA	Misto	Linear
J1073-068	A/C Felt AM 1132	aluminum	HD	010503-3	14.5 mg	IPA	Misto	Linear
J1073-070	A/C Felt AM 1132	aluminum	HD	010503-3	14.5 mg	IPA	Misto	Linear
J1073-074	A/C Fabric AW 1101	aluminum	HD	010503-3	14.5 mg	Hexane	Misto	Linear
J1073-076	A/C Fabric AW 1101	aluminum	HD	010503-3	14.5 mg	Hexane	Misto	Linear
J1073-078	A/C Felt AM 1132	aluminum	HD	010503-3	14.5 mg	Hexane	Misto	Linear
J1073-080	A/C Felt AM 1132	aluminum	HD	010503-3	14.5 mg	Hexane	Misto	Linear
J1073-084	A/C Fabric AW 1101	aluminum	HD	010503-3	1.45 mg	HFE-7200	Misto	Rotary

Table 13. Comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Wipe Material	Test Substrate	Agent	Agent Lot	Agent Deposited	Solvent or Decon	Solvent or Decon Dispenser	Type of Test
J1073-086	A/C Fabric AW 1101	aluminum	HD	010503-3	1.45 mg	None	-	Rotary
J1073-088	A/C Fabric AW 1101	aluminum	HD	010503-3	1.45 mg	HFE-7200	Misto	Rotary
J1073-090	A/C Fabric AW 1101	aluminum	HD	010503-3	14.5 mg	HFE-7200	Misto	Rotary
J1073-092	A/C Fabric AW 1101	aluminum	HD	010503-3	14.5 mg	HFE-7200	Misto	Rotary
J1073-096	A/C Fabric AW 1101	CARC	HD	010503-3	26.1 mg	HFE-7200	Misto	Rotary
J1073-098	A/C Fabric AW 1101	CARC	none	010503-3	control	HFE-7200	Misto	Rotary
J1073-100	A/C Fabric AW 1101	Alkyd	none	010503-3	control	HFE-7200	Misto	Rotary
J1073-102	A/C Fabric AW 1101	Alkyd	HD	010503-3	26.1 mg	HFE-7200	Misto	Rotary
J1073-104	A/C Fabric AW 1101	aluminum	HD	010503-3	14.5 mg	HFE-7200	Misto	Rotary
J1073-108	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
J1073-110	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
J1073-114	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
J1073-120	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
J1073-122	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
J1073-124	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
J1073-126	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	None	-	Rotary
J1190-004	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	None	-	Rotary
J1190-005	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
J1190-010	A/C Felt AM 1132	CARC	HD	010503-3	2.61 mg	None	-	Rotary
J1190-011	A/C Felt AM 1132	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
J1190-016	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	None	Misto	Linear
J1190-017	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Linear
J1190-022	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Linear
J1190-023	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Linear
J1190-026	A/C Felt AM 1132	CARC	HD	010503-3	2.61 mg	None	-	Linear
J1190-027	A/C Felt AM 1132	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Linear
J1190-030	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Linear
J1190-031	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	None	-	Linear
J1190-034	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	HFE-7200	Misto	Linear
J1190-035	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	HFE-7200	Misto	Linear
J1190-038	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	None	-	Linear
J1190-039	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	HFE-7200	Misto	Linear
J1190-042	A/C Felt AM 1132	aluminum	HD	010503-3	14.5 mg	HFE-7200	Misto	Linear
J1190-043	A/C Felt AM 1132	aluminum	HD	010503-3	14.5 mg	HFE-7200	Misto	Linear
J1190-044	A/C Fabric AW 1101	aluminum	HD	010503-3	14.5 mg	HFE-7200	Misto	Linear
J1190-045	A/C Fabric AW 1101	aluminum	HD	010503-3	14.5 mg	HFE-7200	Misto	Linear
J1190-062	A/C Fabric AW 1101	Polycarbonate	HD	010503-3	2.61 mg	None	-	Linear
J1190-063	A/C Fabric AW 1101	Polycarbonate	HD	010503-3	2.61 mg	HFE-7200	Misto	Linear
J1190-072	A/C Fabric AW 1101	Polyethylene	HD	010503-3	2.61 mg	None	-	Linear
J1190-073	A/C Fabric AW 1101	Polyethylene	HD	010503-3	2.61 mg	HFE-7200	-	Linear
J1190-074	None - Surface recovery control	Polycarbonate	HD	010503-3	2.61 mg	None	-	None Control
J1190-075	None - Surface recovery control	Polyethylene	HD	010503-3	2.61 mg	None	-	None Control

Table 13. Comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Wipe Material	Test Substrate	Agent	Agent Lot	Agent Deposited	Solvent or Decon	Solvent or Decon Dispenser	Type of Test
J1190-096	3M Scotch Brite 2021	Polycarbonate	none	010503-3	scratch test	M295 Powder	manual	Rotary
J1190-097	3M Scotch Brite 2021	Polycarbonate	none	010503-3	scratch test	MgO Powder	manual	Rotary
J1190-098	3M Scotch Brite 2021	Polycarbonate	none	010503-3	scratch test	None	-	Rotary
J1190-100	3M Scotch Brite 2021	Polyethylene	HD	010503-3	2.61 mg	M295 Powder	manual	Rotary
J1190-101	3M Scotch Brite 2021	Polyethylene	HD	010503-3	2.61 mg	MgO Powder	manual	Rotary
J1190-102	3M Scotch Brite 2021	Polyethylene	HD	010503-3	2.61 mg	None	-	Rotary
J1190-103	3M Scotch Brite 2021	Polycarbonate	HD	010503-3	2.61 mg	None	-	Rotary
J1190-104	3M Scotch Brite 2021	Polycarbonate	HD	010503-3	2.61 mg	M295 Powder	manual	Rotary
J1190-105	3M Scotch Brite 2021	Polycarbonate	HD	010503-3	2.61 mg	MgO Powder	manual	Rotary
J1190-108	3M Scotch Brite 2021	Mirror	none	010503-3	scratch test	None	-	Rotary
J1190-109	3M Scotch Brite 2021	Mirror	none	010503-3	scratch test	M295 Powder	manual	Rotary
J1190-110	3M Scotch Brite 2021	Mirror	none	010503-3	scratch test	MgO Powder	manual	Rotary
J1190-111	A/C Fabric AW 1101	Polycarbonate	none	010503-3	scratch test	None	-	Rotary
J1190-112	A/C Fabric AW 1101	Polyethylene	none	010503-3	scratch test	None	-	Rotary
J1190-113	A/C Fabric AW 1101	Mirror	none	010503-3	scratch test	None	-	Rotary
J1190-114	3M Scotch Brite 2021	aluminum	HD	010503-3	1.45 mg	M295 Powder	manual	Rotary
J1190-115	A/C Fabric AW 1101	aluminum	HD	010503-3	1.45 mg	MgO Powder	manual	Rotary
J1190-116	A/C Fabric AW 1101	aluminum	HD	010503-3	1.45 mg	M295 Powder	manual	Rotary
J1190-117	3M Scotch Brite 2021	aluminum	HD	010503-3	1.45 mg	MgO Powder	manual	Rotary
J1190-118	3M Scotch Brite 2021	aluminum	HD	010503-3	1.45 mg	None	-	Rotary
J1190-124	3M Scotch Brite 2021	CARC	HD	010503-3	2.61 mg	M295 Powder	manual	Rotary
J1190-125	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	MgO Powder	manual	Rotary
J1190-126	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	M295 Powder	manual	Rotary
J1190-127	3M Scotch Brite 2021	CARC	HD	010503-3	2.61 mg	MgO Powder	manual	Rotary
J1190-128	3M Scotch Brite 2021	CARC	HD	010503-3	2.61 mg	None	-	Rotary
J1190-129	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	None	-	Rotary
J1190-130	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
J1190-131	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
J1190-132	Chamois Cloth	CARC	HD	010503-3	2.61 mg	M295 Powder	manual	Rotary
J1190-133	3M Scotch Brite 2021	Alkyd	HD	010503-3	2.61 mg	M295 Powder	manual	Rotary
J1190-134	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	MgO Powder	manual	Rotary
J1190-135	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	M295 Powder	manual	Rotary
J1190-136	3M Scotch Brite 2021	Alkyd	HD	010503-3	2.61 mg	MgO Powder	manual	Rotary
J1190-137	3M Scotch Brite 2021	Alkyd	HD	010503-3	2.61 mg	None	-	Rotary

Table 13. Comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Wipe Material	Test Substrate	Agent	Agent Lot	Agent Deposited	Solvent or Decon	Solvent or Decon Dispenser	Type of Test
J1190-138	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	None	-	Rotary
J1190-139	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
J1190-140	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
J1190-141	Chamois Cloth	Alkyd	HD	010503-3	2.61 mg	M295 Powder	manual	Rotary
K023-006	A/C Fabric AW 1101	aluminum	HD	010503-3	1.45 mg	None	-	Rotary
K023-007	A/C Fabric AW 1101	aluminum	HD	010503-3	1.45 mg	M295 Powder	manual	Rotary
K023-008	A/C Fabric AW 1101	aluminum	HD	010503-3	1.45 mg	MgO Powder	manual	Rotary
K023-009	A/C Fabric AW 1101	aluminum	HD	010503-3	1.45 mg	HFE-7200	Misto	Rotary
K023-010	A/C Fabric AW 1101	aluminum	HD	010503-3	1.45 mg	None	-	Rotary
K023-011	3M Scotch Brite 2021	aluminum	HD	010503-3	1.45 mg	None	-	Rotary
K023-012	3M Scotch Brite 2021	aluminum	HD	010503-3	1.45 mg	M295 Powder	manual	Rotary
K023-013	3M Scotch Brite 2021	aluminum	HD	010503-3	1.45 mg	MgO Powder	manual	Rotary
K023-014	3M Scotch Brite 2021	aluminum	HD	010503-3	1.45 mg	HFE-7200	Misto	Rotary
K023-015	3M Scotch Brite 2021	aluminum	HD	010503-3	1.45 mg	IPA	Misto	Rotary
K023-022 (2)	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	None	-	Rotary
K023-023 (2)	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
K023-024 (2)	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	IPA	Misto	Rotary
K023-025 (2)	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	M295 Powder	manual	Rotary
K023-026 (2)	A/C Fabric AW 1101	CARC	HD	010503-3	2.61 mg	MgO Powder	manual	Rotary
K023-027 (2)	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	None	-	Rotary
K023-028 (2)	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
K023-029 (2)	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	IPA	Misto	Rotary
K023-030 (2)	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	M295 Powder	manual	Rotary
K023-031 (2)	A/C Fabric AW 1101	Alkyd	HD	010503-3	2.61 mg	MgO Powder	manual	Rotary
K023-032 (2)	3M Scotch Brite 2021	CARC	HD	010503-3	2.61 mg	None	-	Rotary
K023-033 (2)	3M Scotch Brite 2021	CARC	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
K023-034 (2)	3M Scotch Brite 2021	CARC	HD	010503-3	2.61 mg	IPA	Misto	Rotary
K023-035 (2)	3M Scotch Brite 2021	CARC	HD	010503-3	2.61 mg	M295 Powder	manual	Rotary
K023-036 (2)	3M Scotch Brite 2021	CARC	HD	010503-3	2.61 mg	MgO Powder	manual	Rotary
K023-037 (2)	3M Scotch Brite 2021	Alkyd	HD	010503-3	2.61 mg	None	-	Rotary
K023-038 (2)	3M Scotch Brite 2021	Alkyd	HD	010503-3	2.61 mg	HFE-7200	Misto	Rotary
K023-039 (2)	3M Scotch Brite 2021	Alkyd	HD	010503-3	2.61 mg	IPA	Misto	Rotary
K023-040 (2)	3M Scotch Brite 2021	Alkyd	HD	010503-3	2.61 mg	M295 Powder	manual	Rotary
K023-041 (2)	3M Scotch Brite 2021	Alkyd	HD	010503-3	2.61 mg	MgO Powder	manual	Rotary
K023-056 (2)	A/C Fabric AW 1101	Nylon Web	HD	010503-3	1.45 mg	None	-	Rotary
K023-057 (2)	A/C Fabric AW 1101	Nylon Web	HD	010503-3	1.45 mg	HFE-7200	Misto	Rotary
K023-058 (2)	A/C Fabric AW 1101	Nylon Web	HD	010503-3	1.45 mg	IPA	Misto	Rotary
K023-059 (2)	A/C Fabric AW 1101	Nylon Web	HD	010503-3	1.45 mg	M295 Powder	manual	Rotary
K023-060 (2)	A/C Fabric AW 1101	Nylon Web	HD	010503-3	1.45 mg	MgO Powder	manual	Rotary

Table 13. Comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Wipe Material	Test Substrate	Agent	Agent Lot	Agent Deposited	Solvent or Decon	Solvent or Decon Dispenser	Type of Test
K023-062 (2)	A/C Fabric AW 1101	aluminum	VX	020605-4	1.45 mg	None	-	Rotary
K023-063 (2)	A/C Fabric AW 1101	aluminum	VX	020605-4	1.45 mg	HFE-7200	Misto	Rotary
K023-064 (2)	A/C Fabric AW 1101	aluminum	VX	020605-4	1.45 mg	IPA	Misto	Rotary
K023-065 (2)	A/C Fabric AW 1101	aluminum	VX	020605-4	1.45 mg	M295 Powder	manual	Rotary
K023-066 (2)	A/C Fabric AW 1101	aluminum	VX	020605-4	1.45 mg	MgO Powder	manual	Rotary
K023-068 (2)	A/C Fabric AW 1101	Nylon Web	VX	020605-4	1.45 mg	None	-	Rotary
K023-069 (2)	A/C Fabric AW 1101	Nylon Web	VX	020605-4	1.45 mg	HFE-7200	Misto	Rotary
K023-070 (2)	A/C Fabric AW 1101	Nylon Web	VX	020605-4	1.45 mg	IPA	Misto	Rotary
K023-071 (20	A/C Fabric AW 1101	Nylon Web	VX	020605-4	1.45 mg	M295 Powder	manual	Rotary
K023-072 (2)	A/C Fabric AW 1101	Nylon Web	VX	020605-4	1.45 mg	MgO Powder	manual	Rotary
K023-074 (2)	A/C Fabric AW 1101	CARC	VX	020605-4	2.60 mg	None	-	Rotary
K023-075 (2)	A/C Fabric AW 1101	CARC	VX	020605-4	2.60 mg	HFE-7200	Misto	Rotary
K023-076 (2)	A/C Fabric AW 1101	CARC	VX	020605-4	2.60 mg	IPA	Misto	Rotary
K023-077 (2)	A/C Fabric AW 1101	CARC	VX	020605-4	2.60 mg	M295 Powder	manual	Rotary
K023-078 (2)	A/C Fabric AW 1101	CARC	VX	020605-4	2.60 mg	MgO Powder	manual	Rotary
K023-080 (2)	A/C Fabric AW 1101	Alkyd	VX	020605-4	2.60 mg	None	-	Rotary
K023-081 (2)	A/C Fabric AW 1101	Alkyd	VX	020605-4	2.60 mg	HFE-7200	Misto	Rotary
K023-082 (2)	A/C Fabric AW 1101	Alkyd	VX	020605-4	2.60 mg	IPA	Misto	Rotary
K023-083 (2)	A/C Fabric AW 1101	Alkyd	VX	020605-4	2.60 mg	M295 Powder	manual	Rotary
K023-084 (2)	A/C Fabric AW 1101	Alkyd	VX	020605-4	2.60 mg	MgO Powder	manual	Rotary
K023-086 (2)	A/C Fabric AW 1101 - 2 ply	aluminum	VX	020605-4	1.45 mg	None	-	Rotary
K023-088 (2)	A/C Fabric AW 1101	aluminum	TGD	011003-1	1.45 mg	None	-	Rotary
K023-089 (2)	A/C Fabric AW 1101	aluminum	TGD	011003-1	1.45 mg	HFE-7200	Misto	Rotary
K023-090 (2)	A/C Fabric AW 1101	aluminum	TGD	011003-1	1.45 mg	IPA	Misto	Rotary
K023-091 (2)	A/C Fabric AW 1101	aluminum	TGD	011003-1	1.45 mg	M295 Powder	manual	Rotary
K023-092 (2)	A/C Fabric AW 1101	aluminum	TGD	011003-1	1.45 mg	MgO Powder	manual	Rotary
K023-093 (2)	A/C Fabric AW 1101 - 2 ply	aluminum	TGD	011003-1	1.45 mg	None	-	Rotary
K023-095 (2)	A/C Fabric AW 1101	Nylon Web	TGD	011003-1	1.45 mg	None	-	Rotary
K023-096 (2)	A/C Fabric AW 1101	Nylon Web	TGD	011003-1	1.45 mg	HFE-7200	Misto	Rotary
K023-097 (2)	A/C Fabric AW 1101	Nylon Web	TGD	011003-1	1.45 mg	IPA	Misto	Rotary
K023-098 (2)	A/C Fabric AW 1101	Nylon Web	TGD	011003-1	1.45 mg	M295 Powder	manual	Rotary
K023-099 (2)	A/C Fabric AW 1101	Nylon Web	TGD	011003-1	1.45 mg	MgO Powder	manual	Rotary
K023-101 (2)	A/C Fabric AW 1101	CARC	TGD	011003-1	2.60 mg	None	-	Rotary
K023-102 (2)	A/C Fabric AW 1101	CARC	TGD	011003-1	2.60 mg	HFE-7200	Misto	Rotary
K023-103 (2)	A/C Fabric AW 1101	CARC	TGD	011003-1	2.60 mg	IPA	Misto	Rotary
K023-104 (2)	A/C Fabric AW 1101	CARC	TGD	011003-1	2.60 mg	M295 Powder	manual	Rotary
K023-105 (2)	A/C Fabric AW 1101	CARC	TGD	011003-1	2.60 mg	MgO Powder	manual	Rotary
K023-107 (2)	A/C Fabric AW 1101	Alkyd	TGD	011003-1	2.60 mg	None	-	Rotary
K023-108 (2)	A/C Fabric AW 1101	Alkyd	TGD	011003-1	2.60 mg	HFE-7200	Misto	Rotary

Table 13. Comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Wipe Material	Test Substrate	Agent	Agent Lot	Agent Deposited	Solvent or Decon	Solvent or Decon Dispenser	Type of Test
K023-109 (2)	A/C Fabric AW 1101	Alkyd	TGD	011003-1	2.60 mg	IPA	Misto	Rotary
K023-110 (2)	A/C Fabric AW 1101	Alkyd	TGD	011003-1	2.60 mg	M295 Powder	manual	Rotary
K023-111 (2)	A/C Fabric AW 1101	Alkyd	TGD	011003-1	2.60 mg	MgO Powder	manual	Rotary

Table 14. Additional comprehensive list of wipe tests and test parameters.

Test ID (& No. of Replicates)	Mandrel Weight	Wiping Program	Number of Iterations	Wipe 1	Wipe 2	Wipe 3	Placed On Coupon	Sampling Method	Extraction Solvent	Analysis	Surface Temp C	RH %
J906-008a-c	-	-	-	Dry	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	25	22
J906-008d-f	-	-	-	Wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	25	22
J906-014a-c	-	-	-	Dry	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	27	33
J906-014d-f	-	-	-	Wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	27	33
J906-026a-c	-	-	-	Dry	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	26	28
J906-026d-f	-	-	-	Wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	26	28
J906-030a-c	-	-	-	Dry	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	25	53
J906-030d-f	-	-	-	Wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	25	53
J906-034a-c	-	-	-	Dry	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	26	64
J906-034d-f	-	-	-	Wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	26	64
J906-038a-c	-	-	-	Dry	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	27	60
J906-038d-f	-	-	-	Wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	27	60
J906-042a-c	-	-	-	Dry	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	26	60
J906-042d-f	-	-	-	Wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	26	60
J906-046a-c	-	-	-	Dry	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	30	47
J906-046d-f	-	-	-	Wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	30	47
J906-050a-c	-	-	-	Dry	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	28	48
J906-050d-f	-	-	-	Wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	28	48
J906-054a-c	-	-	-	Pre-wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	27	30
J906-059a-b	-	-	-	Pre-wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	27	59
J906-059d-f	-	-	-	Pre-wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	27	59
J906-070a-c	-	-	-	Dry	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	30	32
J906-070d-f	-	-	-	Wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	30	32
J906-078a-c	-	-	-	Pre-wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	26	52
J906-078d-f	-	-	-	Pre-wet	-	-	None	Solvent Extraction	10 mL IPA	GC-FPD	26	52
J906-085a	350 g	G330	1	Dry	-	-	None	DAAMS	-	-	23	51
J906-085b	350 g	G330	1	Wet	-	-	None	DAAMS	-	-	23	53

Table 14. Additional comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Mandrel Weight	Wiping Program	Number of Iterations	Wipe 1	Wipe 2	Wipe 3	Placed On Coupon	Sampling Method	Extraction Solvent	Analysis	Surface Temp C	RH %
J906-090a	350 g	G330	1	Dry	-	-	None	DAAMS	-	-	23	53
J906-090b	350 g	G330	1	Wet	-	-	None	DAAMS	-	-	23	53
J906-094a	350 g	G330	1	Dry	-	-	None	MINICAMS	-	-	23	58
J906-094b	350 g	G330	1	Wet	-	-	None	MINICAMS	-	-	23	58
J906-100a	350 g	G330	1	Dry	Dry	-	None	MINICAMS	-	-	23	59
J906-100b	350 g	G330	1	Wet	Dry	-	None	MINICAMS	-	-	23	59
J906-104 (3)	350 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	22	60
J906-106 (3)	350 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	22	56
J906-110 (3)	350 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	22	55
J906-112 (3)	350 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	22	66
J906-130	350 g	G330	3	Wet	Dry	-	None	ACAMS	-	-	23	58
J906-134 (2)	350 g	G330	3	Wet	Dry	-	None	ACAMS	-	-	-	-
J906-138 (3)	350 g	G330	3	Wet	Dry	-	None	ACAMS	-	-	22	54
J906-142 (3)	350 g	G330	3	Wet	Dry	-	None	ACAMS	-	-	22	57
J973-008 (3)	350 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	23	28
J973-012 (3)	350 g	G330	2	Wet	Dry	-	None	MINICAMS	-	-	24	26
J973-014 (3)	1100 g	G330	2	Wet	Dry	-	None	MINICAMS	-	-	21	33
J973-016 (3)	1100 g	G330	2	Wet	Dry	-	None	MINICAMS	-	-	22	47
J973-022 (3)	1100 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	21	33
J973-026 (3)	350g	G300	3	Wet	Dry	-	None	MINICAMS	-	-	21	29
J973-030 (3)	350 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	21	33
J973-046 (3)	350 g	G330	3	Wet	Dry	-	None	DAAMS1	-	-	21	62
J973-048 (3)	350 g	G330	3	Wet	Dry	-	None	DAAMS1	-	-	21	49
J973-050 (3)	350 g	G330	3	Wet	Dry	-	None	DAAMS1	-	-	21	39
J973-052 (3)	350 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	22	30
J973-054 (3)	350 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	23	31
J973-056 (3)	350 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	23	26
J973-058 (3)	350 g	G330	3	Wet	Wet	Dry	None	MINICAMS	-	-	21	65
J973-060 (3)	350 g	G330	3	Wet	Wet	Dry	None	MINICAMS	-	-	21	68
J973-062 (3)	350 g	G330	3	Wet	Wet	Dry	None	MINICAMS	-	-	22	26
J973-066 (3)	350 g	G330	3	Wet	Wet	Dry	None	MINICAMS	-	-	23	22
J973-070 (3)	350 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	21	23
J973-074 (3)	350 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	23	22
J973-078 (3)	350 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	21	27
J973-082 (3)	350 g	G330	3	Wet	Dry	-	None	MINICAMS	-	-	21	48
J973-088 (3)	350 g	G330	3	Wet	Dry	-	None	Coupon-MCAM Wipes-SE	25/50 mL IPA	GC-FPD	21	33
J973-096 (3)	350 g	G330	3	Wet	Dry	-	None	Coupon-MCAM Wipes-SE	25/50 mL IPA	GC-FPD	22	21
J973-104 (3)	350 g	G330	3	Wet	Dry	-	None	Coupon-MCAM Wipes-SE	25/50 mL IPA	GC-FPD	22	19
J973-114	631 g	G240	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	51

Table 14. Additional comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Mandrel Weight	Wiping Program	Number of Iterations	Wipe 1	Wipe 2	Wipe 3	Placed On Coupon	Sampling Method	Extraction Solvent	Analysis	Surface Temp C	RH %
J973-116	631 g	G240	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	57
J973-118	631 g	G240	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	57
J973-120	631 g	G240	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	20	27
J973-122	631 g	G240	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	20	27
J973-124	631 g	G240	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	20	27
J973-126	631 g	G240	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	60
J973-128	631 g	G240	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	60
J973-130	631 g	G240	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	60
J973-132	631 g	G240	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	60
J973-134	631 g	G240	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	60
J973-136	631 g	G240	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	60
J973-140	631 g	G0	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	51
J973-142	631 g	G0	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	51
J973-144	631 g	G0	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	51
J973-146	631 g	G240	1	Dry	-	-	None	DAAMS1	-	GC-FID	21	49
J973-148	631 g	G0	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	49
J973-150	631 g	G0	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	49
J973-152	631 g	G0	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	49
J973-156	631 g	G240	1	Wet	-	-	None	DAAMS1	-	GC-FID	21	50
J1073-004	631 g	G0	1	Dry	-	-	HFE-7200	Solvent Extraction	25 mL IPA	GC-FPD	22	67
J1073-006	631 g	G0	1	Dry	-	-	HFE-7200	Solvent Extraction	25 mL IPA	GC-FPD	22	67
J1073-008	631 g	G0	1	Dry	-	-	HFE-7200	Solvent Extraction	25 mL IPA	GC-FPD	22	67
J1073-014	631 g	G240	4	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	66
J1073-016	631 g	G240	4	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	66
J1073-018	631 g	G240	4	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	66
J1073-022	631 g	G0	1	Dry	-	-	None	DAAMS1	-	GC-FID	21	52
J1073-026	631 g	G0	1	Dry	-	-	None	DAAMS1-2&3; Solvext-1	25 mL IPA	GC-FID	21	38
J1073-028	631 g	G0	1	Wet	-	-	None	DAAMS1-2&3; Solvext-1	25 mL IPA	GC-FID	21	36
J1073-032	631 g	G0	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	58
J1073-034	631 g	G0	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	58
J1073-038	631 g	G0	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	32
J1073-040	631 g	G0	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	32
J1073-042	631 g	G240	4	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	36

Table 14. Additional comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Mandrel Weight	Wiping Program	Number of Iterations	Wipe 1	Wipe 2	Wipe 3	Placed On Coupon	Sampling Method	Extraction Solvent	Analysis	Surface Temp C	RH %
J1073-044	631 g	G240	4	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	36
J1073-046	631 g	G240	4	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	36
J1073-048	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	36
J1073-050	631 g	G180	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	21	36
J1073-054	631 g	G180	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	58
J1073-056	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	58
J1073-058	631 g	G180	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	58
J1073-060	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	58
J1073-064	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	24	69
J1073-066	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	24	69
J1073-068	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	24	65
J1073-070	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	24	65
J1073-074	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	24	68
J1073-076	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	27	68
J1073-078	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	24	68
J1073-080	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	25	68
J1073-084	350 g	G330	1	Wet	-	-	None	DAAMS1	-	GC-FID	25	65
J1073-086	350 g	G330	1	Dry	-	-	None	DAAMS1	-	GC-FID	25	66
J1073-088	350 g	G330	3	Wet	Dry	-	None	DAAMS1	-	GC-FID	24	62
J1073-090	350 g	G330	3	Wet	-	-	None	MINICAMS	-	GC-FPD	20	34
J1073-092	350 g	G330	3	Wet	-	-	None	MINICAMS	-	GC-FPD	22	35
J1073-096	350 g	G330	3	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	35
J1073-098	350 g	G330	3	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	35
J1073-100	350 g	G330	3	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	35
J1073-102	350 g	G330	3	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	35
J1073-104	350 g	G330	3	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	35
J1073-108	350 g	G330	3	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	21	-
J1073-110	350 g	G330	3	Wet	-	-	None	MINICAMS	-	GC-FPD	22	-
J1073-114	350 g	G330	3	Wet	-	-	None	MINICAMS	-	GC-FPD	22	-
J1073-120	350 g	G330	3	Wet	-	-	HFE-7200	DAAMS2	-	GC-FID	22	-
J1073-122	350 g	G330	3	Wet	-	-	None	DAAMS2	-	GC-FID	22	-
J1073-124	350 g	G330	3	Dry	-	-	HFE-7200	DAAMS2	-	GC-FID	22	-

Table 14. Additional comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Mandrel Weight	Wiping Program	Number of Iterations	Wipe 1	Wipe 2	Wipe 3	Placed On Coupon	Sampling Method	Extraction Solvent	Analysis	Surface Temp C	RH %
J1073-126	350 g	G330	3	Dry	-	-	None	DAAMS2	-	GC-FID	22	-
J1190-004	350 g	G330	3	Dry	-	-	None	DAAMS2	-	GC-FID	24	-
J1190-005	350 g	G330	3	Wet	-	-	None	DAAMS2	-	GC-FID	24	-
J1190-010	350 g	G330	3	Dry	-	-	None	DAAMS2	-	GC-FID	23	-
J1190-011	350 g	G330	3	Wet	-	-	None	DAAMS2	-	GC-FID	23	-
J1190-016	631 g	G240	1	Dry	-	-	None	DAAMS2	-	GC-FID	22	-
J1190-017	631 g	G240	1	Wet	-	-	None	DAAMS2	-	GC-FID	22	-
J1190-022	631 g	G240	1	Dry	-	-	HFE-7200	DAAMS2	-	GC-FID	24	-
J1190-023	631 g	G240	1	Wet	-	-	HFE-7200	DAAMS2	-	GC-FID	24	-
J1190-026	631 g	G240	1	Dry	-	-	None	DAAMS2	-	GC-FID	22	-
J1190-027	631 g	G240	1	Wet	-	-	None	DAAMS2	-	GC-FID	22	-
J1190-030	631 g	G240	1	Wet	-	-	None	DAAMS2	-	GC-FID	24	-
J1190-031	631 g	G240	1	Dry	-	-	None	DAAMS2	-	GC-FID	24	-
J1190-034	631 g	G240	1	Wet	-	-	HFE-7200	DAAMS2	-	GC-FID	22	-
J1190-035	631 g	G240	1	Dry	-	-	HFE-7200	DAAMS2	-	GC-FID	22	-
J1190-038	631 g	G240	1	Dry	-	-	None	DAAMS2	-	GC-FID	22	-
J1190-039	631 g	G240	1	Wet	-	-	None	DAAMS2	-	GC-FID	22	-
J1190-042	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	-
J1190-043	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	-
J1190-044	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	-
J1190-045	631 g	G180	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	-
J1190-062	631 g	G180	1	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	24	-
J1190-063	631 g	G180	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	24	-
J1190-072	631 g	G180	1	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	25	-
J1190-073	631 g	G180	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	25	-
J1190-074	-	-	-	-	-	-	-	Solvent Extraction	50 mL IPA	GC-FPD	25	-
J1190-075	-	-	-	-	-	-	-	Solvent Extraction	50 mL IPA	GC-FPD	25	-
J1190-096	350 g	G330	3	-	-	-	M295	-	-	-	-	-
J1190-097	350 g	G330	3	-	-	-	MgO	-	-	-	-	-
J1190-098	350 g	G330	3	-	-	-	None	-	-	-	-	-
J1190-100	350 g	G330	3	-	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	22	40
J1190-101	350 g	G330	3	-	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	22	40
J1190-102	350 g	G330	3	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	40
J1190-103	350 g	G330	3	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	40
J1190-104	350 g	G330	3	-	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	22	40
J1190-105	350 g	G330	3	-	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	22	40
J1190-108	350 g	G330	3	Dry	-	-	None	-	-	-	-	-

Table 14. Additional comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Mandrel Weight	Wiping Program	Number of Iterations	Wipe 1	Wipe 2	Wipe 3	Placed On Coupon	Sampling Method	Extraction Solvent	Analysis	Surface Temp C	RH %
J1190-109	350 g	G330	3	-	-	-	M295	-	-	-	-	-
J1190-110	350 g	G330	3	-	-	-	MgO	-	-	-	21	57
J1190-111	350 g	G330	3	Dry	-	-	None	-	-	-	21	57
J1190-112	350 g	G330	3	Dry	-	-	None	-	-	-	21	57
J1190-113	350 g	G330	3	Dry	-	-	None	-	-	-	21	57
J1190-114	350 g	G330	3	Dry	-	-	M295	Solvent Extraction	25 mL IPA	GC-FPD	22	62
J1190-115	350 g	G330	3	Dry	-	-	MgO	Solvent Extraction	25 mL IPA	GC-FPD	22	62
J1190-116	350 g	G330	3	Dry	-	-	M295	Solvent Extraction	25 mL IPA	GC-FPD	22	62
J1190-117	350 g	G330	3	Dry	-	-	MgO	Solvent Extraction	25 mL IPA	GC-FPD	22	62
J1190-118	350 g	G330	3	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	62
J1190-124	350 g	G330	3	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-125	350 g	G330	3	Dry	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-126	350 g	G330	3	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-127	350 g	G330	3	Dry	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-128	350 g	G330	3	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-129	350 g	G330	3	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-130	350 g	G330	3	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-131	350 g	G330	3	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-132	350 g	G330	3	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-133	350 g	G330	3	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-134	350 g	G330	3	Dry	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-135	350 g	G330	3	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-136	350 g	G330	3	Dry	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-137	350 g	G330	3	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-138	350 g	G330	3	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-139	350 g	G330	3	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-140	350 g	G330	3	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	63
J1190-141	350 g	G330	3	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	22	63
K023-006	350 g	G300	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	55
K023-007	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	25 mL IPA	GC-FPD	23	55
K023-008	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	25 mL IPA	GC-FPD	23	55
K023-009	350 g	G300	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	55
K023-010	350 g	G300	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	55

Table 14. Additional comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Mandrel Weight	Wiping Program	Number of Iterations	Wipe 1	Wipe 2	Wipe 3	Placed On Coupon	Sampling Method	Extraction Solvent	Analysis	Surface Temp C	RH %
K023-011	350 g	G300	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	55
K023-012	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	25 mL IPA	GC-FPD	23	55
K023-013	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	25 mL IPA	GC-FPD	23	55
K023-014	350 g	G300	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	55
K023-015	350 g	G300	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	55
K023-022 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	23	51
K023-023 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	23	51
K023-024 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	23	51
K023-025 (2)	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	23	51
K023-026 (2)	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	23	51
K023-027 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	23	51
K023-028 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	23	51
K023-029 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	23	51
K023-030 (2)	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	23	51
K023-031 (2)	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	23	51
K023-032 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	24	52
K023-033 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	24	52
K023-034 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	24	52
K023-035 (2)	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	24	52
K023-036 (2)	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	24	52
K023-037 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	24	52
K023-038 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	24	52
K023-039 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	24	52
K023-040 (2)	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	24	52
K023-041 (2)	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	24	52
K023-056 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	61
K023-057 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	61
K023-058 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	61
K023-059 (2)	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	25 mL IPA	GC-FPD	23	61
K023-060 (2)	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	25 mL IPA	GC-FPD	24	59
K023-062 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	61
K023-063 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	61

Table 14. Additional comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Mandrel Weight	Wiping Program	Number of Iterations	Wipe 1	Wipe 2	Wipe 3	Placed On Coupon	Sampling Method	Extraction Solvent	Analysis	Surface Temp C	RH %
K023-064 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	61
K023-065 (2)	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	25 mL IPA	GC-FPD	23	61
K023-066 (2)	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	25 mL IPA	GC-FPD	23	61
K023-068 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	59
K023-069 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	59
K023-070 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	59
K023-071 (20	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	25 mL IPA	GC-FPD	23	59
K023-072 (2)	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	25 mL IPA	GC-FPD	23	59
K023-074 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	62
K023-075 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	62
K023-076 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	62
K023-077 (2)	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	22	62
K023-078 (2)	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	22	62
K023-080 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	62
K023-081 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	62
K023-082 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	22	62
K023-083 (2)	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	22	62
K023-084 (2)	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	22	62
K023-086 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	23	59
K023-088 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	61
K023-089 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	61
K023-090 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	61
K023-091 (2)	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	25 mL IPA	GC-FPD	22	61
K023-092 (2)	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	25 mL IPA	GC-FPD	22	61
K023-093 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	61
K023-095 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	61
K023-096 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	61
K023-097 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	25 mL IPA	GC-FPD	22	61
K023-098 (2)	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	25 mL IPA	GC-FPD	22	61
K023-099 (2)	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	25 mL IPA	GC-FPD	22	61

Table 14. Additional comprehensive list of wipe tests and test parameters (continued).

Test ID (& No. of Replicates)	Mandrel Weight	Wiping Program	Number of Iterations	Wipe 1	Wipe 2	Wipe 3	Placed On Coupon	Sampling Method	Extraction Solvent	Analysis	Surface Temp C	RH %
K023-101 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	23	61
K023-102 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	23	61
K023-103 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	23	61
K023-104 (2)	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	23	61
K023-105 (2)	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	23	61
K023-107 (2)	350 g	G300	1	Dry	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	23	61
K023-108 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	23	61
K023-109 (2)	350 g	G300	1	Wet	-	-	None	Solvent Extraction	50 mL IPA	GC-FPD	23	61
K023-110 (2)	350 g	G300	1	Dry	-	-	M295	Solvent Extraction	50 mL IPA	GC-FPD	23	61
K023-111 (2)	350 g	G300	1	Dry	-	-	MgO	Solvent Extraction	50 mL IPA	GC-FPD	23	61

7.1 HD Rotary-Wiping Screening Tests of Potential Wiping Materials

Based on prior work conducted at Entropic Systems, Inc., the agent-wiping studies under the JSSED Block III program focused on three wiping materials—activated carbon fiber (KoTHmex AW 1101), activated carbon felt (KoTHmex AM 1132), and a non-adsorptive microfiber cloth (3M Scotch-Brite 2021). However, during the course of the program, several additional commercial and developmental wipes were tested for comparison with the activated carbon and microfiber wipes.

The bulk of the screening tests of potential wiping materials were conducted at the start of the test program while the automated rotary and linear wipe test apparatuses were being fabricated. A preliminary set of manual decontamination efficacy screening tests on flat stainless steel surfaces was conducted with neat sulfur mustard (HD) and 14 different wiping materials. The wiping procedures used in the tests were designed to simulate the rotary-wiping procedures that would subsequently be used in tests with the automated rotary wipe test apparatus and are described in Section 6.2.

The manual rotary-wiping tests were conducted with:

- 3M Scotch-Brite 2011
- 3M Scotch-Brite 2021N
- Activated Carbon Felt
- Activated Carbon Fiber
- Procter and Gamble Swiffer
- Polyester Felt
- Pledge Grab-It wipes
- Teri Reinforced Wipers
- Cutex Non-alcohol Pad
- Clorox Disinfecting Wipes – Fresh Scent
- Clorox Disinfecting Wipes – Lemon Scent
- Bounty Paper towels
- Lever 2000 Wipes
- Safety Equipment Cleaning Pads

Subsequent screening tests were conducted with HD on aluminum control surfaces, using the automated rotary-wiping apparatus with the following wipes:

- Teri Reinforced Wiper
- Wypall® X70 Workhorse® Manufactured Rags

The results of the manual-wiping tests are summarized in Table 15. Table 16 lists a summary of the automated rotary-wiping tests. Table 15 lists the wiping material, solvent (if used), test number, test date, the amount of HD recovered from the test coupon, and the calculated mass of HD per volume per time for each test. The tests conducted with wipes that were moistened with HFE-7200 are shaded in the table for clarity. The results presented have not been corrected for extraction efficiency.

Decontamination Efficacy (DE) is calculated from the following equation:

$$DE = \frac{(\text{Amount of Agent Initially Deposited - Amount of Residual Agent})}{(\text{Amount of Agent Initially Deposited})} \times 100\% \qquad \text{Equation 2}$$

Table 15. Summary of HD manual rotary-wiping screening tests of potential wiping materials.

Wipe Method – Manual Rotary: One clockwise revolution at 0.1 rev/s followed by one counterclockwise revolution at 0.1 rev/s
HD Contamination Amount—10 mg Weight of Aluminum Wipe Cylinder—1 lb. Sampling and Analysis Method—Solvent Extraction (IPA)-GC/FPD

Wiping Material	Solvent	Test No.	Date	HD Recovered From Coupon µg	Decon Efficacy %
3M Scotch-Brite 2011	None	J906-008a	05/23/01	56.0	99.5
3M Scotch-Brite 2011	None	J906-008b	05/23/01	140	98.6
3M Scotch-Brite 2011	None	J906-008c	05/23/01	92.7	99.1
3M Scotch-Brite 2011	HFE-7200	J906-008d	05/23/01	186	98.2
3M Scotch-Brite 2011	HFE-7200	J906-008e	05/23/01	359	96.4
3M Scotch-Brite 2011	HFE-7200	J906-008f	05/23/01	69	99.3
3M Scotch-Brite 2011	None	J906-014a	05/29/01	41.8	99.6
3M Scotch-Brite 2011	None	J906-014b	05/29/01	94.4	99.1
3M Scotch-Brite 2011	None	J906-014c	05/29/01	117	98.8
3M Scotch-Brite 2011	HFE-7200	J906-014d	05/29/01	125	98.8
3M Scotch-Brite 2011	HFE-7200	J906-014e	05/29/01	314	96.9
3M Scotch-Brite 2011	HFE-7200	J906-014f	05/29/01	245	97.6
Activated Carbon Felt	None	J906-026a	05/30/01	49.6	99.5
Activated Carbon Felt	None	J906-026b	05/30/01	56.0	99.4
Activated Carbon Felt	None	J906-026c	05/30/01	-**	-**
Activated Carbon Felt	HFE-7200	J906-026d	05/30/01	68.1	99.3
Activated Carbon Felt	HFE-7200	J906-026e	05/30/01	40.9	99.6
Activated Carbon Felt	HFE-7200	J906-026f	05/30/01	93.1	99.1
Activated Carbon Fiber	None	J906-030a	05/31/01	7.70	99.9
Activated Carbon Fiber	None	J906-030b	05/31/01	6.78	99.9
Activated Carbon Fiber	None	J906-030c	05/31/01	7.26	99.9
Activated Carbon Fiber	HFE-7200	J906-030d	05/31/01	9.60	99.9
Activated Carbon Fiber	HFE-7200	J906-030e	05/31/01	23.5	99.8
Activated Carbon Fiber	HFE-7200	J906-030f	05/31/01	23.5	99.8
Proctor and Gamble Swiffer	None	J906-034a	06/01/01	4157	58.4
Proctor and Gamble Swiffer	None	J906-034b	06/01/01	4343	56.6
Proctor and Gamble Swiffer	None	J906-034c	06/01/01	4312	56.9
Proctor and Gamble Swiffer	HFE-7200	J906-034d	06/01/01	961	90.4
Proctor and Gamble Swiffer	HFE-7200	J906-034e	06/01/01	1514	84.9
Proctor and Gamble Swiffer	HFE-7200	J906-034f	06/01/01	1181	88.2
Polyester Felt	None	J906-038a	06/07/01	1074	89.3
Polyester Felt	None	J906-038b	06/07/01	1897	81.1
Polyester Felt	None	J906-038c	06/07/01	872	91.3

Table 15. Summary of HD manual rotary-wiping screening tests of potential wiping materials (continued).

Wipe Method – Manual Rotary: One clockwise revolution at 0.1 rev/s followed by one counterclockwise revolution at 0.1 rev/s
HD Contamination Amount—10 mg   Weight of Aluminum Wipe Cylinder—1 lb.   Sampling and Analysis Method—Solvent Extraction (IPA)-GC/FPD

Wiping Material	Solvent	Test No.	Date	HD Recovered From Coupon µg	Decon Efficacy %
Polyester Felt	HFE-7200	J906-038d	06/07/01	983	90.2
Polyester Felt	HFE-7200	J906-038e	06/07/01	557	94.4
Polyester Felt	HFE-7200	J906-038f	06/07/01	234	97.7
Pledge "Grab-It" Wipes	None	J906-042a	06/11/01	3883	61.2
Pledge "Grab-It" Wipes	None	J906-042b	06/11/01	4321	56.8
Pledge "Grab-It" Wipes	None	J906-042c	06/11/01	4954	50.5
Pledge "Grab-It" Wipes	HFE-7200	J906-042d	06/11/01	1708	82.9
Pledge "Grab-It" Wipes	HFE-7200	J906-042e	06/11/01	2583	74.4
Pledge "Grab-It" Wipes	HFE-7200	J906-042f	06/11/01	1624	83.8
Teri Reinforced Wipers	None	J906-046a	06/13/01	13.0	99.9
Teri Reinforced Wipers	None	J906-046b	06/13/01	133	98.7
Teri Reinforced Wipers	None	J906-046c	06/13/01	24.2	99.8
Teri Reinforced Wipers	HFE-7200	J906-046d	06/13/01	31.0	99.7
Teri Reinforced Wipers	HFE-7200	J906-046e	06/13/01	157	98.4
Teri Reinforced Wipers	HFE-7200	J906-046f	06/13/01	53.5	99.5
3M Scotch-Brite 2021N	None	J906-050a	06/14/01	25.9	99.7
3M Scotch-Brite 2021N	None	J906-050b	06/14/01	54.5	99.5
3M Scotch-Brite 2021N	None	J906-050c	06/14/01	58.1	99.4
3M Scotch-Brite 2021N	HFE-7200	J906-050d	06/14/01	269	97.3
3M Scotch-Brite 2021N	HFE-7200	J906-050e	06/14/01	<5	>99.9
3M Scotch-Brite 2021N	HFE-7200	J906-050f	06/14/01	10.4	99.9
Cutex Simple Pad (non-acetone)*	Ethyl acetate/IPA/Water	J906-054a	06/19/01	168	98.3
Cutex Simple Pad (non-acetone)*	Ethyl acetate/IPA/Water	J906-054b	06/19/01	137	98.6
Cutex Simple Pad (non-acetone)*	Ethyl acetate/IPA/Water	J906-054c	06/19/01	332	96.7
Clorox Disinfecting Wipes – Lemon*	1—5% Aqueous IPA	J906-059a	06/20/01	495	95.1
Clorox Disinfecting Wipes – Lemon*	1—5% Aqueous IPA	J906-059b	06/20/01	607	94.0
Clorox Disinfecting Wipes – Fresh*	1—5% Aqueous IPA	J906-059d	06/20/01	396	96.1
Clorox Disinfecting Wipes – Fresh*	1—5% Aqueous IPA	J906-059e	06/20/01	737	92.7
Clorox Disinfecting Wipes – Fresh*	1—5% Aqueous IPA	J906-059f	06/20/01	524	94.8
Bounty Paper Towels	None	J906-070a	06/25/01	312	96.9
Bounty Paper Towels	None	J906-070b	06/25/01	201	98.8
Bounty Paper Towels	None	J906-070c	06/25/01	145	98.5
Bounty Paper Towels	HFE-7200	J906-070d	06/25/01	601	94.0
Bounty Paper Towels	HFE-7200	J906-070e	06/25/01	994	90.1
Bounty Paper Towels	HFE-7200	J906-070f	06/25/01	673	93.3
Lever 2000 Wipes*	70-99% Water	J906-078a	06/28/01	365	96.4
Lever 2000 Wipes*	70-99% Water	J906-078b	06/28/01	338	96.6
Lever 2000 Wipes*	70-99% Water	J906-078c	06/28/01	112	98.9
Safety Equipment Cleaning Pads*	>99% Water	J906-078d	06/28/01	3430	65.7
Safety Equipment Cleaning Pads*	>99% Water	J906-078e	06/28/01	4491	55.6
Safety Equipment Cleaning Pads*	>99% Water	J906-078f	06/28/01	5479	45.2

*Note: The materials marked with an asterisk were pre-moistened with their own solvent and were evaluated as received.

** The residual HD found in Test J906-026c is anomalously high and is not included in the test results.

Table 16. Summary of HD automated rotary-wiping screening tests of potential wiping materials.

Wiping Material	Test Surface	Wipe Method	Added Solvent	Test No.	Wiping Sequence	Sampling Method	No. of Wiping Cycles	Total Mandrel Weight	HD Contamination	HD Recovered From Coupon	Decon Efficacy %
Teri Reinforced Wipers	Aluminum	Rotary	HFE-7200	J906-110	Wet/Dry	MINI CAMS	24	350	10	0.856	>99.99
Teri Reinforced Wipers	Aluminum	Rotary	HFE-7200	J906-110	Wet/Dry	MINI CAMS	24	350	10	0.132	>99.99
Teri Reinforced Wipers	Aluminum	Rotary	HFE-7200	J906-110	Wet/Dry	MINI CAMS	24	350	10	0.099	>99.99
Wypall X70	Aluminum	Rotary	HFE-7200	J973-066	Wet/Dry	MINI CAMS	24	350	10	0.092	>99.99
Wypall X70	Aluminum	Rotary	HFE-7200	J973-066	Wet/Dry	MINI CAMS	24	350	10	0.428	>99.99
Wypall X70	Aluminum	Rotary	HFE-7200	J973-066	Wet/Dry	MINI CAMS	24	350	10	0.155	>99.99

* Pre-Moistened with HFE-7200

The Teri Towels did not maintain their integrity during the wiping procedure, and tended to shred during the wipe tests.

The manual wiping tests (see Appendix B) were conducted under identical arbitrary wiping conditions that were assumed to be less than thorough, in order to allow for some residual agent to remain on the stainless steel surfaces so that comparisons could be made between the various wiping materials. The wiping materials evaluated were the three wipe material candidates that had been pre-selected, based on prior work by Entropic Systems, Inc. (activated carbon fiber, activated carbon felt, and 3M Scotch Brite 2001), several commercial wipes, and several wiping materials from the laboratory's stockroom. The initial screening tests were intended as preliminary tests to check the proposed wipe test procedures. These procedures would be used in tests with the automated rotary-wiping test apparatus, while comparing the decontamination efficacies of several wiping materials in removing liquid HD contamination from a non-absorptive control surface.

Under the conditions of the manual decontamination efficacy tests, the activated carbon cloth, activated carbon felt, 3M Scotch-Brite 2001, and Teri Reinforced Wipers (Teri Towels) showed roughly equivalent wiping efficacies of >99%. The efficacies of these four materials were superior to the corresponding decontamination efficacies of the other wipes tested. Testing also found that using these four "best" wipes dry exhibited decontamination efficacies as good as, or slightly better than, the corresponding decontamination efficacies of the same wipes moistened with HFE-7200.

7.2 Preliminary Tests with Rotary-Wiping Device

Eight preliminary agent wipe tests were conducted at ambient temperature and relative humidity with HD with the rotary-wiping device. Each test was conducted using the 350 g aluminum rotary-wiping mandrel, with no added weight, and a single iteration of the G330 rotary-wiping program command. The G330 command activates eight sequential clockwise/counterclockwise cycles of the wiping mandrel. Each rotational cycle consists of one clockwise revolution at a rate of 1.0 rev/s, followed by one counterclockwise revolution at 1.0 rev/s.

- Each of the first four tests were conducted with medium weight 3M Scotch-Brite 2001 wipes, using DAAMS sampling and analysis to determine the amount of residual HD off-gassing from the wiped surface.

- The remaining four tests were conducted with KoTHmex AW 1101-activated carbon fabric, using MINICAMS to monitor the residual HD off-gassing from the wiped surface.

During testing, the surface of a 1.5 x 1.5 in. square aluminum test coupon was mounted in the rotary-wiping device and uniformly contaminated with 10 mg of neat HD, applied as 1 μL droplets from a microliter syringe. The wiping mandrel, with a preattached wipe (dry in some tests and wet with HFE-7200 in other tests), was placed on top of the agent-contaminated surface so that the turning pin on the shaft of the stepper motor was positioned in the slotted shaft of the wiping mandrel. Then the G330-wiping command was input to the wiping device from the control PC.

After the wiping procedure was complete, the wiped test coupon was placed in a glass sampling jar with an air inlet and outlet fitting in the cap of the jar. Room air was sampled into and through the jar into either a DAAMS sorbent tube or a MINICAMS. DAAMS tubes were subsequently analyzed for collected agent by GC/FPD. The collected MINICAMS samples were analyzed directed by the MINICAMS. Each jar was sampled and analyzed for residual agent vapor for up to 2 h.

The results of the preliminary wiping tests are shown in Table 17. The initial goal of the wiping tests was to decontaminate each test coupon, resulting in an agent vapor off-gassing concentration of no greater than a few TWA.

In the first six tests using a single wipe, whether dry or moistened with HFE-7200, the initial HD off-gassing concentration was generally off-scale of our analytical equipment (estimated to be equivalent to a concentration of approximately 30 TWA of HD).

In tests seven and eight, each contaminated surface was wiped with two wipes in succession. In test seven a dry wipe, followed by another dry wipe with a fresh swatch of material, was tested. In test eight, a wipe moistened with HFE-7200 followed by a dry wipe, were used. As shown in Table 17, this dual-wipe procedure resulted in the desired agent off-gassing concentrations, with the wet/dry wipe sequence superior to the dry/dry wipe sequence.

Plots of the measured HD off-gassing concentration, as a function of time, in the two dual-wipe tests are shown in Figure 16 and Figure 17. The test data was also tabulated and plotted in terms of off-gassing rate (in ng/min), as a function of time. This off-gassing curve was numerically integrated over the monitoring duration to determine the cumulative amounts of HD that off-gassed from the wiped surfaces. The cumulative residual HD on the test coupon subjected to the dry/dry wipe procedure was 100 ng. The cumulative residual HD on the test coupon subjected to the wet/dry wipe procedure was 35 ng.

Table 17. Summary of preliminary HD wipe tests on aluminum surfaces with automated rotary-wiping test apparatus.

Wiping Material	Solvent	Test No.	Wiping Sequence	Sampling Method	No. of Wiping Cycles	Total Mandrel Weight g	Cumulative Off-Gassing ng	HD Contami-nation Amount mg	Decon Efficacy %
Scotch-Brite	None	J906-085	Dry	DAAMS	8	350	ND (Note 1)	10	ND (Note 1)
Scotch-Brite	HFE-7200	J906-085	Wet	DAAMS	8	350	ND (Note 1)	10	ND (Note 1)
Scotch-Brite	None	J906-090	Dry	DAAMS	8	350	ND (Note 1)	10	ND (Note 1)
Scotch-Brite	HFE-7200	J906-090	Wet	DAAMS	8	350	ND (Note 1)	10	ND (Note 1)
AC Fabric	None	J906-094	Dry	MINICAMS	8	350	ND (Note 1)	10	ND (Note 1)
AC Fabric	HFE-7200	J906-094	Wet	MINICAMS	8	350	ND (Note 1)	10	ND (Note 1)
AC Fabric	None	J906-100	Dry/Dry	MINICAMS	8	350	100	10	>99.99
AC Fabric	HFE-7200	J906-100	Wet/Dry	MINICAMS	8	350	35	10	>99.99

Note 1: ND = Not Determined. Test Terminated after analysis of sample. Initial HD concentration is well above calibration range.

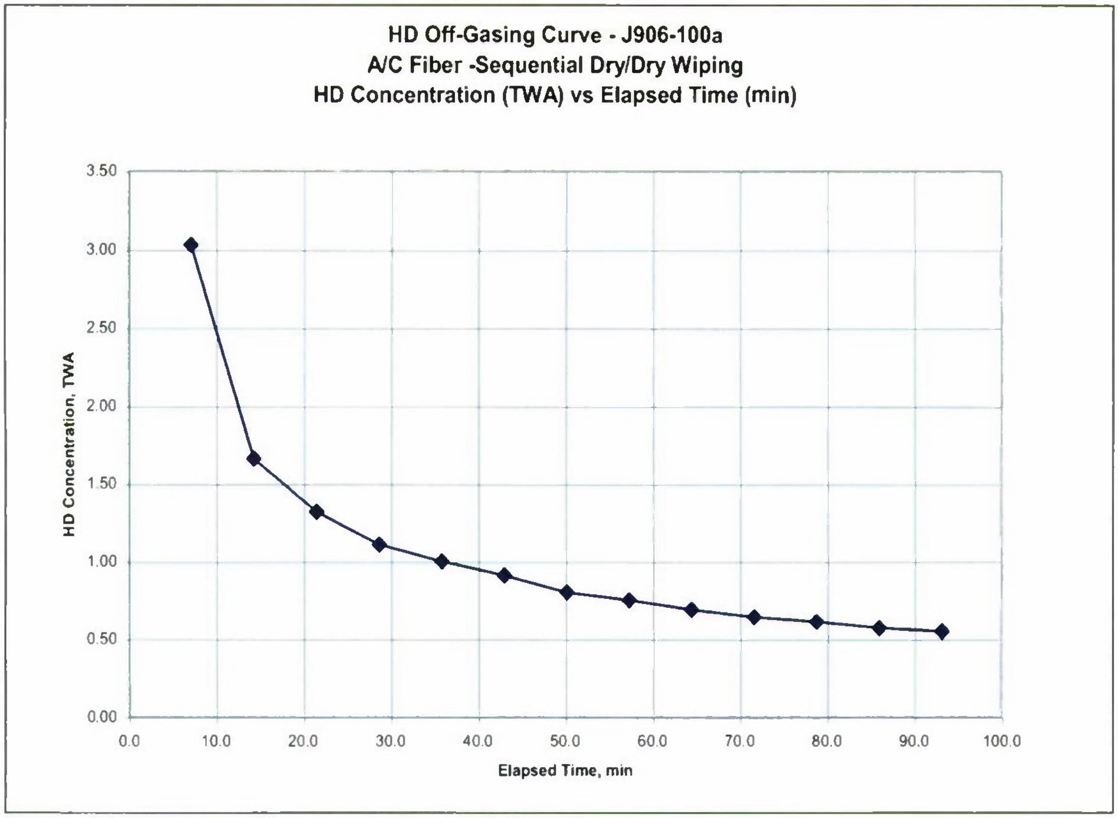


Figure 16. HD vapor off-gas curve - test J978-026(A).

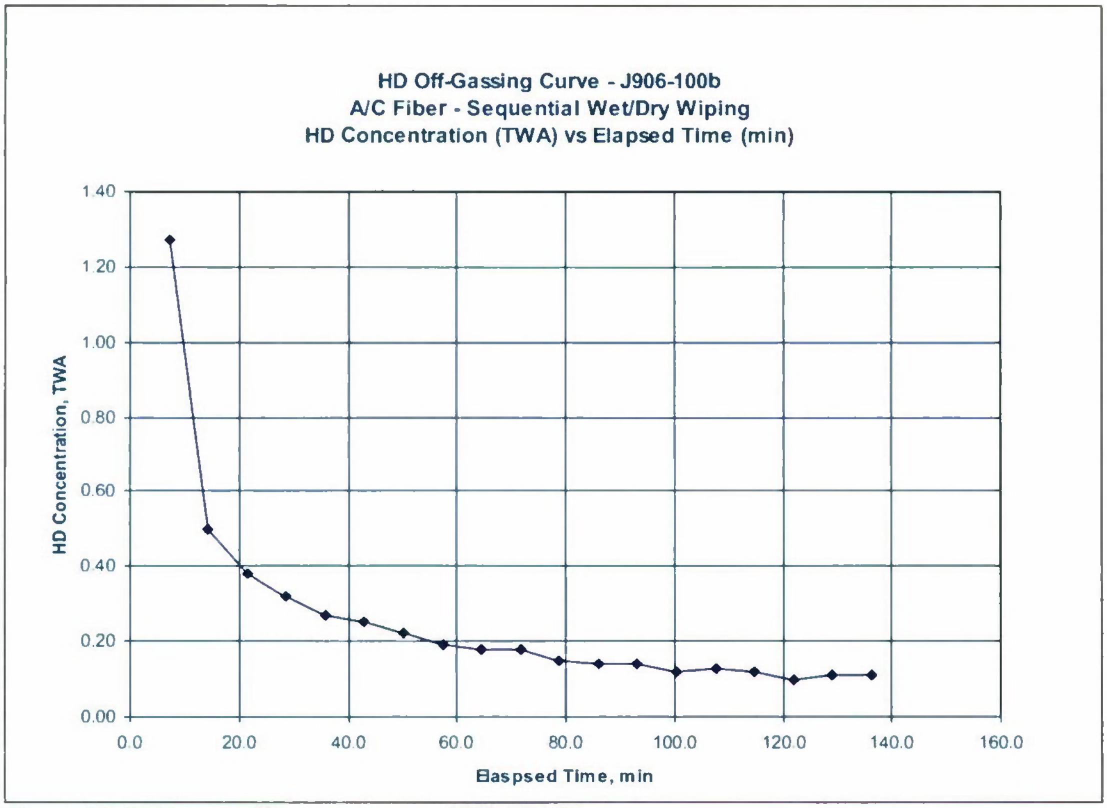


Figure 17. HD vapor off-gas curve - test J978-026(B).

7.3 HD Automated Rotary-Wiping Tests on Non-Absorptive Aluminum Surfaces

A series of multiple-wipe tests with HD were conducted with the rotary-wiping device on aluminum substrates at ambient temperature and relative humidity to determine the effect of the number and type of rotary-wiping cycles, the weight of the wiping mandrel, and the wiping solvent on the efficacy of removing HD from aluminum control surfaces. The tests were conducted with the KoTHmex AW 1101-activated carbon fabric, KoTHmex AM 1132-activated carbon felt, and Scotch-Brite 2021.

Tests were conducted with HD on aluminum substrates, using the rotary wipe test apparatus and dynamic vapor off-gas monitoring for residual agent on the wiped test coupons. The tests were conducted at ambient temperature and relative humidity. Most of the tests were conducted using the 350-g aluminum rotary-wiping mandrel, with no added weight. However, in a few of the tests, lead washers were slipped over the shaft of the rotary-wiping mandrel to increase the total mandrel weight to 1100 g. The tests were conducted with either two or three iterations of the G330 rotary-wiping program or three iteration of the G300 program.

- The G330 command activates eight sequential clockwise/counterclockwise cycles of the wiping mandrel. Each rotational cycle consists of one clockwise revolution at a rate of 1.0 rev/s, followed by one counterclockwise revolution at 1.0 rev/s. Thus, the wiping contact time is 32 s for two iterations, and 48 s for three iterations.

- The G300 command activates four sequential clockwise/counterclockwise cycles of the wiping mandrel. Each rotational cycle consists of one clockwise revolution at a rate of 1.0 rev/s, followed by one counterclockwise revolution at 1.0 rev/s. Thus, the wiping contact time is 24 s for three iterations.

Both single and multiple wipe sequences were used in this series of tests:

- <u>Dry</u>: In each dry-wipe test, a single wipe sequence with a dry wipe was used.

- <u>Wet</u>: In each wet-wipe test, a wipe moistened with HFE-7200 was used for each wipe sequence.

- <u>Dry/Dry</u>: In each dry/dry test, two wipe sequences were used, each with a dry wipe.

- <u>Wet/Dry</u>: In each wet/dry test, two wipe sequences were employed—one sequence using a wipe moistened with a solvent (either HFE-7200 or HFE-71 IPA), followed immediately by a second wipe sequence using a dry wipe.

- <u>Wet/Wet</u>: In each wet/wet test, two wipe sequences were employed—the first sequence using a wipe moistened with HFE-7200, followed immediately by a second wipe sequence using a wipe moistened with HFE-7200.

- <u>Wet/Wet/Dry</u>: In each wet/wet/dry sequence, three wipe sequences were employed—the first sequence using a wipe moistened with HFE-7200, followed immediately by a second wipe sequence using a wipe moistened with HFE-7200, followed immediately by a third wipe sequence using a dry wipe.

The purpose of the wet/wet and wet/wet/dry multiple-wipe tests was to determine if increased removal of HD from the aluminum test surface (that is, increased decontamination efficacy) could be achieved with an additional "wet" wipe sequence, relative to the wet/dry dual wipe sequence, with and without a final dry wipe sequence.

The wiping materials evaluated in the tests were:

- Activated carbon fabric – KoTHmex AW 1101
- Activated carbon felt – KoTHmex AM 1132
- Non-adsorptive wipes – 3M Scotch-Brite™ 2011 High Performance Cloth

The sampling and analysis of the wiped coupons for residual agent (HD) off-gassing from the wiped test surface was conducted with either a MINICAMS or by the DAAMS method.

In a given test, the surface of a 1.5 x 1.5 in. square aluminum test coupon was mounted in the rotary-wiping device. The coupon was uniformly contaminated with 10 mg of neat HD, applied as 1 µL droplets from a microliter syringe or as five approximately 2 µL droplets from a micropipettor in a pattern similar to the five dots found on a pair of dice, over a center 1 in. square of the test coupon.

The wiping mandrel with a preattached wipe (dry in some tests and moistened with HFE-7200 or HFE-711PA in other tests) was placed on top of the agent-contaminated surface so that the turning pin on the shaft of the stepper motor was positioned in the slotted shaft of the wiping mandrel. Two or three iterations of the G330-wiping command or three iterations of the G300 wiping command were then sequentially input to the wiping device from the control PC.

After each wipe sequence, the mandrel was immediately replaced with a new wiping mandrel having a preattached dry or wet wipe, and another wipe test sequence was initiated.

The results of the individual HD-wiping tests are shown in chronological order in Table 18. In Table 18, the wiping material, wipe solvent, test number, wipe sequence, sampling method for the determination of residual HD on the test coupon, number of wiping cycles, total mandrel weight, cumulative residual HD on the wipe test coupon (from the numerical integration of the vapor off-gas curve), the amount of HD initially deposited on the test surface, and the calculated decontamination efficacy of the wiping process are listed for each test.

The individual results listed in Table 18 are summarized in Table 19. In Table 19 each set of tests conducted under a given set of experimental conditions and parameters is grouped together. In each grouped set of tests, the primary experimental variable or parameter that was changed from the previous set of tests is shaded in yellow. The parameters that were varied in the tests were:

- Wiping material
- AC Fabric = KoTHmex AW 1101-activated carbon fabric
- AC Felt = KoTHmex AM 1132-activated carbon felt
- Scotch-Brite = 3M Scotch-Brite 2021
- Mandrel weight

- 350 g
- 1100 g
- Wiping solvent
- HFE-7100
- HFE-71IPA
- Number of wiping cycles
  - 24
  - 16
  - 12
- Wiping sequence
- Wet/Dry
- Wet/Wet
- Wet/Wet/Dry

Table 18. HD-wiping tests with rotary-wiping device on aluminum surface.

Wiping Material	Solvent	Test No.	Wiping Sequence	Sampling Method	No. of Wiping Cycles	Total Mandrel Weight G	Cumulative Off-Gassing ng	HD Contami-nation Amount	Decon Efficacy %
AC Fiber	HFE-7200	J906-104	Wet/Dry	MINICAMS	24	350	72	10	>99.99
AC Fiber	HFE-7200	J906-104	Wet/Dry	MINICAMS	24	350	40	10	>99.99
AC Fiber	HFE-7200	J906-104	Wet/Dry	MINICAMS	24	350	39	10	>99.99
						Average	50 ± 19		>99.99
Scotch-Brite	HFE-7200	J906-106	Wet/Dry	MINICAMS	24	350	176	10	>99.99
Scotch-Brite	HFE-7200	J906-106	Wet/Dry	MINICAMS	24	350	97	10	>99.99
Scotch-Brite	HFE-7200	J906-106	Wet/Dry	MINICAMS	24	350	72	10	>99.99
						Average	115 ± 54		>99.99
AC Felt	HFE-7200	J906-112	Wet/Dry	MINICAMS	24	350	93	10	>99.99
AC Felt	HFE-7200	J906-112	Wet/Dry	MINICAMS	24	350	168	10	>99.99
AC Felt	HFE-7200	J906-112	Wet/Dry	MINICAMS	24	350	8	10	>99.99
						Average	90 ± 80		>99.99
AC Fiber	HFE-7200	J973-008	Wet/Dry	MINICAMS	24	350	49	10	>99.99
AC Fiber	HFE-7200	J973-008	Wet/Dry	MINICAMS	24	350	41	10	>99.99
AC Fiber	HFE-7200	J973-008	Wet/Dry	MINICAMS	24	350	24	10	>99.99
						Average	38 ± 13		>99.99
AC Fiber	HFE-7200	J973-012	Wet/Dry	MINICAMS	16	350	120	10	>99.99
AC Fiber	HFE-7200	J973-012	Wet/Dry	MINICAMS	16	350	77	10	>99.99
AC Fiber	HFE-7200	J973-012	Wet/Dry	MINICAMS	16	350	47	10	>99.99
						Average	81 ± 37		>99.99
AC Fiber	HFE-7200	J973-014	Wet/Dry	MINICAMS	16	1100	210	10	>99.99
AC Fiber	HFE-7200	J973-014	Wet/Dry	MINICAMS	16	1100	113	10	>99.99
AC Fiber	HFE-7200	J973-014	Wet/Dry	MINICAMS	16	1100	79	10	>99.99
						Average	134 ± 68		>99.99
AC Fiber	HFE-7200	J973-016	Wet/Dry	MINICAMS	16	1100	121	10	>99.99
AC Fiber	HFE-7200	J973-016	Wet/Dry	MINICAMS	16	1100	131	10	>99.99
AC Fiber	HFE-7200	J973-016	Wet/Dry	MINICAMS	16	1100	109	10	>99.99
						Average	120 ± 11		>99.99
AC Fiber	HFE-7200	J973-022	Wet/Dry	MINICAMS	24	1100	140	10	>99.99
AC Fiber	HFE-7200	J973-022	Wet/Dry	MINICAMS	24	1100	77	10	>99.99
AC Fiber	HFE-7200	J973-022	Wet/Dry	MINICAMS	24	1100	163	10	>99.99
						Average	127 ± 44		>99.99
AC Fiber	HFE-7200	J973-026	Wet/Dry	MINICAMS	12	350	307	10	>99.99
AC Fiber	HFE-7200	J973-026	Wet/Dry	MINICAMS	12	350	161	10	>99.99
AC Fiber	HFE-7200	J973-026	Wet/Dry	MINICAMS	12	350	295	10	>99.99
						Average	255 ± 81		>99.99

Table 18. HD-wiping tests with rotary-wiping device on aluminum surface (continued).

Wiping Material	Solvent	Test No.	Wiping Sequence	Sampling Method	No. of Wiping Cycles	Total Mandrel Weight G	Cumulative Off-Gassing ng	HD Contamination Amount	Decon Efficacy %
AC Felt	HFE-7200	J973-030	Wet/Dry	MINICAMS	24	350	518	10	>99.99
AC Felt	HFE-7200	J973-030	Wet/Dry	MINICAMS	24	350	92	10	>99.99
AC Felt	HFE-7200	J973-030	Wet/Dry	MINICAMS	24	350	198	10	>99.99
						Average	145 ± 75		>99.99
AC Fiber	HFE-7200	J973-046	Wet/Dry	DAAMS	24	350	47	10	>99.99
AC Fiber	HFE-7200	J973-046	Wet/Dry	DAAMS	24	350	37	10	>99.99
AC Fiber	HFE-7200	J973-046	Wet/Dry	DAAMS	24	350	59	10	>99.99
						Average	49 ± 11		>99.99
AC Felt	HFE-7200	J973-048	Wet/Dry	DAAMS	24	350	15	10	>99.99
AC Felt	HFE-7200	J973-048	Wet/Dry	DAAMS	24	350	14	10	>99.99
AC Felt	HFE-7200	J973-048	Wet/Dry	DAAMS	24	350	36	10	>99.99
						Average	22 ± 12		>99.99
Scotch-Brite	HFE-7200	J973-050	Wet/Dry	DAAMS	24	350	98	10	>99.99
Scotch-Brite	HFE-7200	J973-050	Wet/Dry	DAAMS	24	350	394	10	>99.99
Scotch-Brite	HFE-7200	J973-050	Wet/Dry	DAAMS	24	350	493	10	>99.99
						Average	328 ± 205		>99.99
AC Fiber	HFE-7200	J973-052	Wet/Wet	MINICAMS	24	350	Not analyzed	10	>99.99
AC Fiber	HFE-7200	J973-052	Wet/Wet	MINICAMS	24	350	16	10	>99.99
AC Fiber	HFE-7200	J973-052	Wet/Wet	MINICAMS	24	350	19	10	>99.99
						Average	17 ± 2		>99.99
AC Felt	HFE-7200	J973-054	Wet/Wet	MINICAMS	24	350	9	10	>99.99
AC Felt	HFE-7200	J973-054	Wet/Wet	MINICAMS	24	350	32	10	>99.99
AC Felt	HFE-7200	J973-054	Wet/Wet	MINICAMS	24	350	152	10	>99.99
						Average	20 ± 16*		>99.99
Scotch-Brite	HFE-7200	J973-056	Wet/Wet	MINICAMS	24	350	121	10	>99.99
Scotch-Brite	HFE-7200	J973-056	Wet/Wet	MINICAMS	24	350	203	10	>99.99
Scotch-Brite	HFE-7200	J973-056	Wet/Wet	MINICAMS	24	350	60	10	>99.99
						Average	128 ± 72		>99.99
AC Fiber	HFE-7200	J973-062	Wet/Wet/Dry	MINICAMS	24	350	123	10	>99.99
AC Fiber	HFE-7200	J973-062	Wet/Wet/Dry	MINICAMS	24	350	9	10	>99.99
AC Fiber	HFE-7200	J973-062	Wet/Wet/Dry	MINICAMS	24	350	3	10	>99.99
						Average	6 ± 4*		>99.99

Table 18. HD-wiping tests with rotary-wiping device on aluminum surface (continued).

Wiping Material	Solvent	Test No.	Wiping Sequence	Sampling Method	No. of Wiping Cycles	Total Mandrel Weight G	Cumulative Off-Gassing ng	HD Contami-nation Amount	Decon Efficacy %
AC Felt	HFE-7200	J973-058	Wet/Wet/ Dry	MINICAMS	24	350	15	10	>99.99
AC Felt	HFE-7200	J973-058	Wet/Wet/ Dry	MINICAMS	24	350	11	10	>99.99
AC Felt	HFE-7200	J973-058	Wet/Wet/ Dry	MINICAMS	24	350	10	10	>99.99
						Average	12 ± 3		>99.99
Scotch-Brite	HFE-7200	J973-060	Wet/Wet/ Dry	MINICAMS	24	350	52	10	>99.99
Scotch-Brite	HFE-7200	J973-060	Wet/Wet/ Dry	MINICAMS	24	350	156	10	>99.99
Scotch-Brite	HFE-7200	J973-060	Wet/Wet/ Dry	MINICAMS	24	350	90	10	>99.99
						Average	99 ± 53		>99.99
AC Fiber	HFE-71 IPA	J973-070	Wet/Dry	MINICAMS	24	350	116	10	>99.99
AC Fiber	HFE-71 IPA	J973-070	Wet/Dry	MINICAMS	24	350	97	10	>99.99
AC Fiber	HFE-71 IPA	J973-070	Wet/Dry	MINICAMS	24	350	67	10	>99.99
						Average	94 ± 25		>99.99
AC Felt	HFE-71 IPA	J973-074	Wet/Dry	MINICAMS	24	350	477	10	>99.99
AC Felt	HFE-71 IPA	J973-074	Wet/Dry	MINICAMS	24	350	246	10	>99.99
AC Felt	HFE-71 IPA	J973-074	Wet/Dry	MINICAMS	24	350	70	10	>99.99
						Average	264 ± 204		>99.99
Scotch-Brite	HFE-71 IPA	J973-078	Wet/Dry	MINICAMS	24	350	>197	10	>99.99
Scotch-Brite	HFE-71 IPA	J973-078	Wet/Dry	MINICAMS	24	350	>290	10	>99.99
Scotch-Brite	HFE-71 IPA	J973-078	Wet/Dry	MINICAMS	24	350	>179	10	>99.99
						Average	>222		>99.99
AC Fiber	HFE-7200	J973-082	Wet/Dry	MINICAMS	24	350	148	10	>99.99
AC Fiber	HFE-7200	J973-082	Wet/Dry	MINICAMS	24	350	137	10	>99.99
AC Fiber	HFE-7200	J973-082	Wet/Dry	MINICAMS	24	350	121	10	>99.99
						Average	135 ± 13		>99.99

All tests conducted in triplicate

* = Anomalous high result not included in average

AC Fiber = KoTHmex AW 1101-activated carbon fabric.
AC Felt = KoTHmex AM 1132-activated carbon felt.
Scotch-Brite = 3M Scotch-Brite 2021
Wet = wet with HFE-7200
Dry = dry wiping material

Table 19. Summary of HD-wiping tests with rotary-wiping device on aluminum surface.

Wiping Material	Solvent	Wiping Sequence	No. of Wiping Cycles	Total Mandrel Weight g	Cumulative Off-Gassing ng
AC Fiber	HFE-7200	Wet/Dry	24	350	68 ± 43
AC Fiber	HFE-71IPA	Wet/Dry	24	350	93 ± 25
AC Fiber	HFE-7200	Wet/Dry	16	350	81 ± 37
AC Fiber	HFE-7200	Wet/Dry	12	350	254 ± 81
AC Fiber	HFE-7200	Wet/Dry	24	1100	127 ± 45
AC Fiber	HFE-7200	Wet/Dry	16	1100	127 ± 44
AC Fiber	HFE-7200	Wet/Wet	24	350	18 ± 2
AC Fiber	HFE-7200	Wet/Wet/Dry	24	350	6 ± 4
AC Felt	HFE-7200	Wet/Dry	24	350	127 ± 162
AC Felt	HFE-71IPA	Wet/Dry	24	350	264 ± 204
AC Felt	HFE-7200	Wet/Wet	24	350	21 ± 16
AC Felt	HFE-7200	Wet/Wet/Dry	24	350	12 ± 3
Scotch-Brite	HFE-7200	Wet/Dry	24	350	222 ± 178
Scotch-Brite	HFE-71IPA	Wet/Dry	24	350	>222
Scotch-Brite	HFE-7200	Wet/Wet	24	350	128 ± 72
Scotch-Brite	HFE-7200	Wet/Wet/Dry	24	350	99 ± 53

Large absolute variabilities were observed in the off-gassing results of replicate determinations in most of the tests. However, this is not unexpected at the low levels of agent off-gassing that are being monitored, and the unavoidable uncertainty in the actual t=0 point in each vapor off-gas curve. This is due to the fact that the vapor off-gassing curves exhibit exponential decay. The location of the t=0 point of an off-gassing curve has a significant effect on the determination of the cumulative amount of agent sampled by the numerical integration of the area under the off-gassing curve.

In three of the triplicate test sets, two of the test results showed very low residual HD amounts on the wiped test surfaces, whereas one of the tests in each set showed significantly higher residual HD amounts.

The measured residual agent amounts on the aluminum control surfaces determined by off-gas monitoring were quite variable. The tentative conclusion from the vapor off-gassing tests is that the minimum residual agent that can be accurately and reproducibly detected on the wiped control surface is about 0.1 μg.

Unaccountably high residual HD amounts were detected in several of the tests. These results appeared to be anomalous and were not reported in the results summary in Table 18 or Table 19.

In each of the tests the decontamination efficacy for the removal of HD from the non-porous aluminum test surface was >99.99%, based on a vapor sampling technique as described in Section 7.6.2. These results are not necessarily a comparison to ORD Vapor Hazard Threshold or Objective values. Within experimental error, there were no significant differences in measured decontamination efficacies attributable to changes in any of the variables or parameters listed above.

From the residual amount of HD remaining on the aluminum surface in each test, however, even though the limited test results have large variabilities and mostly statistically inconclusive differences in test results comparing various test parameters, several trends in the average amounts of residual agent can be noted.

Trend 1: Adsorptive carbon wipes remove liquid HD more effectively from non-adsorptive aluminum control surfaces than non-adsorptive wipes. KoTHmex AW 1101-activated carbon fiber appears to be the most effective wipe, followed closely by KoTHmex AM 1132-activated carbon felt, and then by the 3M Scotch-Brite 2021 wipes. In the tests run under the same set of conditions (350 g mandrel, 24 wipe cycles, wet/dry wipe sequence, HFE-7200 wipe solvent, and MINICAMS vapor off-gas monitoring) the average cumulative HD off-gassing with each of the wipe materials tested was as follows:

KoTHmex AW 1101-activated carbon fiber	68 ng
KoTHmex AM 1132-activated carbon felt	127 ng
3M Scotch-Brite 2021	222 ng

The tests conducted using DAAMS analysis also show that the 3M Scotch-Brite 2021 material is somewhat less effective at removing deposited HD from the aluminum test surface (using HFE-7200) than either of the two carbon-based fabrics.

In terms of the wiping materials themselves, the AC fiber and the AC felt materials were about equivalent and showed the best decontaminant efficacy results. The 3M Scotch-Brite 2021 material is somewhat less effective at removing deposited HD from the aluminum test surface (using HFE-7200) than either of the carbon-based fabrics. However, the use of Scotch-Brite 2021 still resulted in decontamination efficacies in excess of 99.99%.

Trend 2: Increased mandrel weight has no significant effect on the removal of liquid agent from the aluminum control surfaces.

AC Fiber/350 g mandrel/24 wiping cycles	68 ng residual HD
AC Fiber/1100 g mandrel/24 wiping cycles	127 ng residual HD
AC Fiber/350 g mandrel/16 wiping cycles	81 ng residual HD
AC Fiber/1100 g mandrel/16 wiping cycles	127 ng residual HD

Trend 3. Reducing the number of wiping cycles in the rotary-wiping tests with a 350 g mandrel resulted in slightly less removal of HD from the aluminum control surfaces. In the tests with a 100 g mandrel, no change in HD removal was observed. In the wet/dry rotary-wiping tests with HFE-7200, activated carbon fiber, 350 g mandrel weight, and MINICAMS vapor off-gas monitoring, reducing the number of wipe cycles from 24 to 16 to 12 wipe cycles resulted in an observed increase in residual HD on the aluminum control surfaces (as determined from the cumulative HD off-gassing amounts):

For 350 g mandrel weight:	For 1100-g mandrel weight:
24 wipe cycles – 68 ng residual HD	24 wipe cycles – 127 ng residual HD
16 wipe cycles – 81 ng residual HD	16 wipe cycles – 127 ng residual HD
12 wipe cycles – 254 ng residual HD	

Trend 4. HFE-71 IPA is no more effective than HFE-7200 as a wipe solvent in removing HD from an aluminum control surface. Because of the variability in the determination of the residual agent on the test surface by off-gas monitoring, it is difficult to statistically quantify any differences. However, the general trend is as follows:

AC Fiber/HFE-7200	68 ng residual HD
AC Fiber/HFE-71IPA	93 ng residual HD
AC Felt/HFE-7200	127 ng residual HD
AC Felt/HFE-71IPA	264 ng residual HD
Scotch-Brite/HFE-7200	222 ng residual HD
Scotch-Brite/HFE-71IPA	>222 ng residual HD

Trend 5. The use of an additional wet wiping sequence increases the removal of HD from the aluminum control surface (Table 20). The use of a wet-wet wiping sequence appears to increase the decontamination efficacy for each wiping material relative to the wet-dry wiping sequence. The use of a wet-wet-dry multiple wipe sequence increases the decontamination efficacy for each wiping material somewhat more. Within the error of the experimental method, the wet-wet-dry sequence appears to be the maximum decontamination efficacy obtainable from rotary wiping, with a reasonable number of wiping sequences.

Table 20. Summary of effect of additional wet wiping sequences on HD rotary wiping.

Wiping Material	Solvent	Wiping Sequence	No. of Wiping Cycles	Total Mandrel Weight g	Cumulative Off-Gassing ng
AC Fiber	HFE-7200	Wet/Dry	24	350	68
AC Fiber	HFE-7200	Wet/Wet	24	350	18
AC Fiber	HFE-7200	Wet/Wet/Dry	24	350	6
AC Felt	HFE-7200	Wet/Dry	24	350	127
AC Felt	HFE-7200	Wet/Wet	24	350	21
AC Felt	HFE-7200	Wet/Wet/Dry	24	350	12
Scotch-Brite	HFE-7200	Wet/Dry	24	350	222
Scotch-Brite	HFE-7200	Wet/Wet	24	350	128
Scotch-Brite	HFE-7200	Wet/Wet/Dry	24	350	99

Trend 6. A comparison of DAAMS vs. MINICAMS sampling showed differences. DAAMS sampling, and analysis of the of the test coupons that were wiped with the activated carbon fabrics (fiber and felt), gave lower residual HD amounts than MINICAMS sampling and analysis, especially in the tests with the activated carbon felt wipes. In the tests with the non-adsorptive wipes, the opposite tend was observed. Because of the very small amounts of residual agent that are being detected, however, the difference in the trends between the two sampling-and-analysis methods is not considered significant. In terms of measured decontamination efficacy, within the accuracy of the tests, there is little difference between the sampling and analysis techniques.

Additional HD rotary-wiping tests were conducted on aluminum control surfaces with both higher and lower HD contamination densities than were used in the previous tests discussed above. The densities used were 10 g/m^2 (generally considered the standard outdoor threat contamination density) and 1 g/m^2 (generally considered the standard indoor threat contamination density). On the aluminum test coupons these contamination densities corresponded to HD contamination amounts of 14.5 and 1.45 mg, respectively. All subsequent tests under the program were conducted at one of these two agent contamination densities.

In addition to sampling and analyzing the coupons, each used wet or dry wipe was also sampled and analyzed for absorbed/adsorbed HD after the completion of wiping.

In the first set of tests, three replicate HD automated rotary-wiping tests were conducted on aluminum control surfaces with KoTHmex AW 1101-activated carbon fiber, KoTHmex AM 1132-activated carbon felt, and 3M Scotch-Brite 2021. The HD contamination density in each test was 10 g/m^2. Each test was conducted with a wet/dry wiping sequence, with HFE-7200 as the wiping solvent, a 350 g rotary mandrel weight, and 24 wiping cycles per wipe sequence. The residual HD remaining on each aluminum control surface after wiping was determined by MINICAMS sampling and analysis. The amount of absorbed/adsorbed HD in each used wipe was determined by solvent extraction and GC-FPD analysis.

The results of the tests are given in Table 21 below.

The test results indicate that the HD decontamination efficacy with HFE 7200 and each of the three wiping materials remained the same when the HD contamination density was increased from 7 to 10 g/m^2. As shown in the table immediately below, there was no statistical difference in the amounts of residual HD recovered from the aluminum control surfaces between the earlier tests with a HD contamination density of 7 g/m^2 and the tests in Table 22 with a HD contamination density of 10 g/m^2.

Table 21. Amount of residual HD on post-wiped aluminum control surfaces.

	HD Contamination Density	
Wipe Material	**7 g/m^2**	**10 g/m^2**
AC Fiber	69 ± 43 ng	94 ± 16 ng
AC Felt	127 ± 162 ng	167 ± 88 ng
Scotch-Brite	222 ± 178 ng	297 ± 229 ng

The results of the extraction and GC-FPD analysis of each of the dry and wet wiping materials for absorbed/adsorbed HD, showed that approximately 100% of the initially deposited HD was recovered from the 3M Scotch-Brite 2021 wipe, with greater than 95% of the HD recovered from the first (wet) wipe.

In the tests with the two activated carbon fabrics, 67% of the initially deposited HD was recovered from the KoTHmex AW 1101-activated carbon fabric wipes, and 46% of the initially deposited HD was recovered from the KoTHmex AM 1132-activated carbon felt wipes. Almost all of the recovered HD came from the first (wet) wipe. The lower HD recovery from the activated carbon wipes is a measure of the adsorptive capacities of the two wiping materials. In the tests with all three wipes, however, the results clearly show that most of the initially deposited HD is removed in the first wet wipe sequence.

Table 22. HD Rotary-wiping tests on aluminum control surfaces with wipe analysis (solvent extraction).

Wiping Material	Solvent	Test No.	Wiping Sequence	Sampling Method	No. of Wiping Cycles	Total Mandrel Weight g	Cumulative Off-Gassing µg	HD Contamination Amount mg	Decon Efficacy %	HD Recovered from Wet Wipe mg	HD Recovered from Dry Wipe mg
AC Fiber	HFE-7200	J973-088	Wet/Dry	MINICAMS	24	350	0.079	14.5	>99.99	8.15	<1
AC Fiber	HFE-7200	J973-088	Wet/Dry	MINICAMS	24	350	0.092	14.5	>99.99	11.68	<1
AC Fiber	HFE-7200	J973-088	Wet/Dry	MINICAMS	24	350	0.110	14.5	>99.99	9.11	<1
						Average	0.094 ± 0.016		>99.99	9.7 ± 1.7	<1
AC Felt	HFE-7200	J973-096	Wet/Dry	MINICAMS	24	350	0.180	14.5	>99.99	3.72	0.04
AC Felt	HFE-7200	J973-096	Wet/Dry	MINICAMS	24	350	0.247	14.5	>99.99	10.22	0.05
AC Felt	HFE-7200	J973-096	Wet/Dry	MINICAMS	24	350	0.073	14.5	>99.99	5.04	0.03
						Average	0.167 ± 0.088		>99.99	6.6 ± 3.1	0.04 ± 0.01
Scotch-Brite	HFE-7200	J973-104	Wet/Dry	MINICAMS	24	350	0.555	14.5	>99.99	5.81	0.04
Scotch-Brite	HFE-7200	J973-104	Wet/Dry	MINICAMS	24	350	0.116	14.5	>99.99	15.20	0.01
Scotch-Brite	HFE-7200	J973-104	Wet/Dry	MINICAMS	24	350	0.221	14.5	>99.99	16.09	0.17
						Average	0.297 ± 0.229		>99.99	12.4 ± 5.1	0.07 ± 0.07

AC Fabric = KoTHmex AW 1101-activated carbon fabric.
AC Felt = KoTHmex AM 1132-activated carbon felt.
Scotch-Brite = 3M Scotch-Brite 2021
Wet = wet with HFE-7200
Dry = dry wiping material

In the second set of tests, three HD automated rotary-wiping tests were conducted on aluminum control surfaces using KoTHmex AW 1101-activated carbon fiber wipes with a HD contamination density of 1 g/m^2 in each test. The first test was conducted with a wipe moistened with HFE-7200, the second test with a dry wipe, and the third test with a wet/dry wiping sequence. Each of the first two tests was conducted with a reduced wiping sequence—eight wiping cycles, referred to as *cursory wiping*. The third test was conducted with 24 wipe cycles for each wet and dry wiping sequence. Each test was conducted with HFE-7200 as the wiping solvent and a 350 g rotary mandrel weight. The residual HD remaining on each aluminum control surface after wiping was determined by DAAMS sampling and GC-FID analysis. The amount of absorbed/adsorbed HD in each used wipe was also determined by DAAMS sampling and Gas Chromatography-Flame Ionization Detector (GC-FID) analysis. The results of the tests are given in Table 23.

The decontamination efficacy of surface HD removal from a non-absorptive aluminum control surface was ≥99.96% in all three tests. As was expected on the basis of the previous HD rotary-wiping tests results under the same set of conditions, the decontamination efficacy in the test with 24 wiping cycles of a wet/dry wiping sequence (denoted as thorough wiping) was superior to the decontamination efficacies in the tests with eight wiping cycles. And, as observed nearly consistently throughout the test program, the decontamination efficacy with a dry AC Fiber wipe was as effective as or slightly more effective than the decontamination efficacy with a solvent-moistened AC Fiber wipe.

Only 90 ng of HD was found to have off-gassed from the HFE-7200-moistened AC Fiber wipe after the completion of the wipe sequence in the single wet-wipe test, 226 ng of HD from the dry wipe in the single dry-wipe test, 57 ng of HD from the wet wipe in the wet/dry-wipe test, and no detectable HD from the dry wipe in the wet/dry-wipe test. Even with a ten times smaller initial HD contamination density on the aluminum control surface, the amount of HD recovered from the adsorptive wipes by vapor off-gassing was much less than the amount recovered by solvent extraction. In terms of the practical use of an adsorptive wipe system, these results are very positive and indicate relatively low potential post-wipe HD contamination hazard from the used wipe before it is bagged and sealed for future disposal.

7.4 TGD Rotary-Wiping Tests with Vapor Monitoring

A series of dual-wipe (that is wet wipe followed by dry wipe, or wet/dry) tests with TGD were conducted on non-absorptive aluminum control surfaces at room temperature and ambient relative humidity with the automated rotary-wiping device under the same test conditions as the HD wipe tests discussed in Section 7.3. Each of the TGD tests was conducted using the 350 g aluminum rotary-wiping mandrel with no added weight. In each test, two wipe sequences were employed—one sequence with a dry wipe, followed immediately by a second wipe sequence with a wipe moistened with HFE-7200. Each wipe sequence consisted of three iterations of the G330 rotary-wiping program command (24 wipe cycles).

Three tests were conducted with KoTHmex AW 1101-activated carbon fabric, three tests with 3M Scotch-Brite 2021, and three tests with KoTHmex AM 1132-activated carbon felt. The residual GD remaining on each aluminum control surface after wiping was determined by ACAMS sampling and analysis, as described in Section 7.3.

Table 23. Summary of HD-wiping tests on aluminum control surfaces with rotary wipe test apparatus analysis of agent off-gassing from both the test coupons and the activated carbon fabric wipes.

Test Conditions: Either one or three iterations of the G330 wiping program_eight clockwise/counterclockwise revolutions to simulate either cursory or thorough wiping

Wipe Speed – 1 rev/s
Single aluminum test coupon
Low (indoor) HD contamination density – 1.0 g/m2
Comparison of the following three wiping sequences:
--Wet wipe (HFE-7200), cursory wiping
--Dry wipe (no solvent), cursory wiping
--Wet wipe (HFE-7200) followed by dry wipe (no solvent), thorough wiping

Wiping Material	Wiping Solvent	Test No.	Wiping Sequence	Sampling Method	No. of Wiping Cycles	Total Mandrel Weight g	Off-Gassing From Coupon µg	HD Contamination Amount mg	Decon Efficacy %	HD Off-Gassing from Wet Wipe µg	HD Off-Gassing from Dry Wipe µg
AC Fiber	HFE-7200	J1073-084	Wet	DAAMS	8	350	0.574	1.45	99.96	0.090	-
AC Fiber	None	J1073-086	Dry	DAAMS	8	350	0.136	1.45	99.99	-	0.226
AC Fiber	HFE-7200	J1073-088	Wet/Dry	DAAMS	24	350	0.014	1.45	>99.99	0.057	0.000

AC Fabric = KoTHmex AW 1101-activated carbon fabric.
Wet = Wipe moistened with HFE-7200
Dry = Dry wiping material

In a given test, the surface of a 1.5 x 1.5 in. square aluminum test coupon was mounted in the rotary-wiping device. The coupon was uniformly contaminated with 10 mg of TGD, applied as five approximately 2 μL droplets from a micropipettor in a pattern similar to the five dots found on a pair of dice, over a center 1 in. square of the test coupon.

The wiping mandrel, with a preattached wipe wetted with HFE-7200, was placed on top of the agent-contaminated surface so that the turning pin on the shaft of the stepper motor was positioned in the slotted shaft of the wiping mandrel. The three iterations of the G330-wiping command were then sequentially input to the wiping device from the control PC. The wiping mandrel was then replaced with a new wiping mandrel having a preattached dry wipe, and a second wipe test sequence with three iterations of the G330-wiping command was conducted.

After the wiping procedure was complete, the wiped test coupon was placed in a glass sampling jar with air inlet and outlet fitting in the cap of the jar. Room air was sampled into and through the jar into an ACAMS. The collected samples were analyzed directed by the ACAMS. Each jar was sampled and analyzed for residual agent vapor for up to 2 h.

The results for each of the tests are given in Table 24.

Table 24. Summary of preliminary TGD wiping tests with rotary-wiping device on aluminum surface.

Wiping Material	Solvent	Test No.	Wiping Sequence	Sampling Method	No. of Wiping Cycles (1)	Total Mandrel Weight g	Cumulative Off-Gassing ng	GD Contami-nation Amount mg (2)	Decon Efficacy %
AC Fiber	HFE-7200	J906-130	Wet/Dry	ACAMS	24	350	110	9.5	>99.99
AC Fiber	HFE-7200	J906-134a	Wet/Dry	ACAMS	24	350	593	9.5	>99.99
AC Fiber	HFE-7200	J906-134b	Wet/Dry	ACAMS	24	350	58	9.5	>99.99
						Average	84 ± 37*		>99.99
Scotch-Brite	HFE-7200	J906-142a	Wet/Dry	ACAMS	24	350	190	9.5	>99.99
Scotch-Brite	HFE-7200	J906-142b	Wet/Dry	ACAMS	24	350	55	9.5	>99.99
Scotch-Brite	HFE-7200	J906-142c	Wet/Dry	ACAMS	24	350	117	9.5	>99.99
						Average	121 ± 68		>99.99
AC Felt	HFE-7200	J906-138a	Wet/Dry	ACAMS	24	350	325	9.5	>99.99
AC Felt	HFE-7200	J906-138b	Wet/Dry	ACAMS	24	350	66	9.5	>99.99
AC Felt	HFE-7200	J906-138c	Wet/Dry	ACAMS	24	350	53	9.5	>99.99
						Average	148 ± 153		>99.99

Note 1. Each test was conducted with three iterations of the G330 rotary-wiping program for each of the two wipe sequences (wet and then dry).

Note 2. Amount of TGD deposited in each tests was 10 mg. Five percent of this amount was thickener.

* Anomalous high result not included in average

Although there is significant variability from test to test in the measured cumulative GD permeation, as in the HD tests with MINICAMS monitoring, the average residual GD found on the wiped aluminum control surfaces in the tests with each of the wipe materials is roughly the same as the average residual HD found on the wiped aluminum control surfaces in the corresponding HD rotary-wiping tests discussed above:

Wipe Material	Residual HD	Residual GD
AC Fiber	68 ± 83 ng	84 ± 37 ng
AC Felt	127 ± 162 ng	148 ± 153 ng
Scotch-Brite	222 ± 178 ng	121 ± 68 ng

7.5 Comparison of HD and TGD Vapor Off-Gas Curves

A set of representative TGD vapor off-gassing curves is shown in Figure 18 through Figure 20.

Figure 18 shows the GD vapor off-gas curve for Test J906-130 (conducted with AC Fiber wipes) in terms of absolute GD concentration (in units of ng/L) as a function of elapsed time (in min) and in terms of GD hazard level (in concentration units of TWA) as function of elapsed time (in min).

Figure 19 shows the GD vapor off-gas curve for Test J906-138c (conducted with AC Felt wipes) in terms of both absolute GD concentration and GD hazard level as a function of elapsed time. For comparison with the previous HD testing, Figure 20 shows a representative HD vapor off-gas curve (from Test J973-026b conducted with AC Fiber wipes and discussed earlier in Section 7.2) in terms of both absolute HD concentration and HD hazard level as a function of elapsed time.

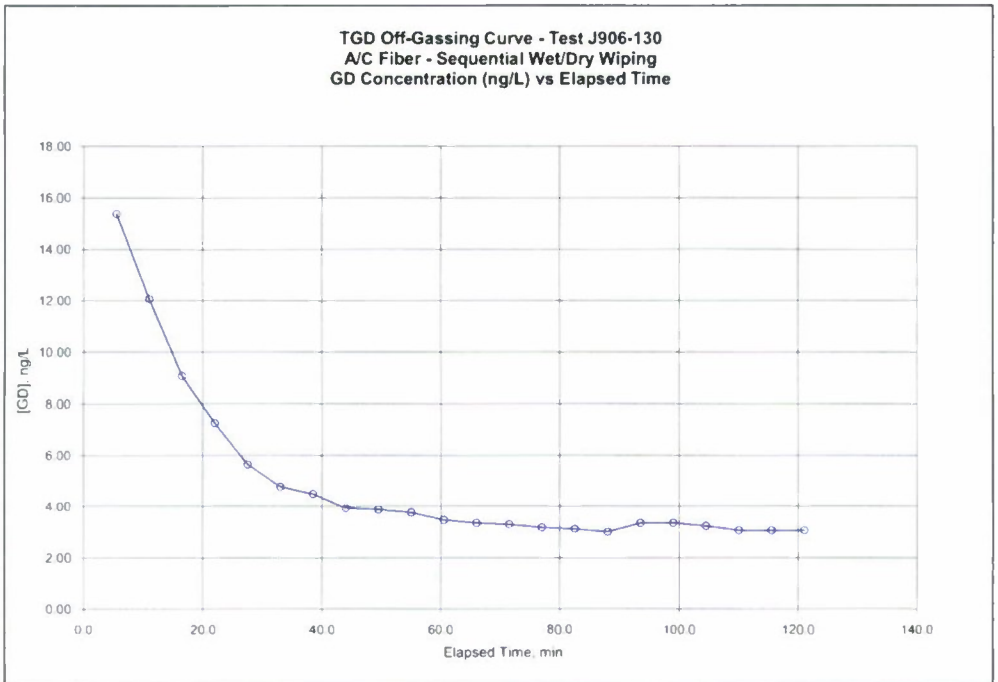
In terms of decontamination efficacy, all three of the wipes evaluated in the TGD rotary-wiping tests were effective in removing greater than 99.99% of the TGD deposited on the aluminum test surfaces, essentially the identical decontamination efficacies that were determined in the HD wipe tests.

In terms of vapor off-gas monitoring, a comparison of the absolute GD concentration as a function of elapsed time in Figure 18, Figure 19, and Figure 20 show that the absolute surface removal and residual off-gassing concentrations of GD and HD are nearly the same in the TGD and HD rotary-wiping tests.

However, a comparison of the vapor off-gas curves in Figure 18, Figure 19, and Figure 20, shows that the hazard level of residual GD vapor concentrations, off-gassing from the wiped tests surfaces after 120 min, generally ranged from 40 to greater than 200 TWA. This was far in excess of acceptable hazard levels.

The reason for the large observed hazard levels of off-gassing GD (relative to the low HD hazard levels observed) is that the allowable exposure level of GD is 100 times lower than the allowable exposure level for HD (on the basis of the AELs in AR 385-61)—0.003 mg/m^3 for HD and 0.00003 mg/m^3 for GD. Otherwise, the wiping removal efficiency of TGD is nearly the same as the removal efficiency observed for HD.

Because the allowable exposure level of VX is another factor of three lower than that of GD, the use of agent vapor off-gassing to assess the effectiveness of a Block III sensitive equipment decontamination procedure, in terms of residual agent vapor hazard will be feasible for HD contamination only.



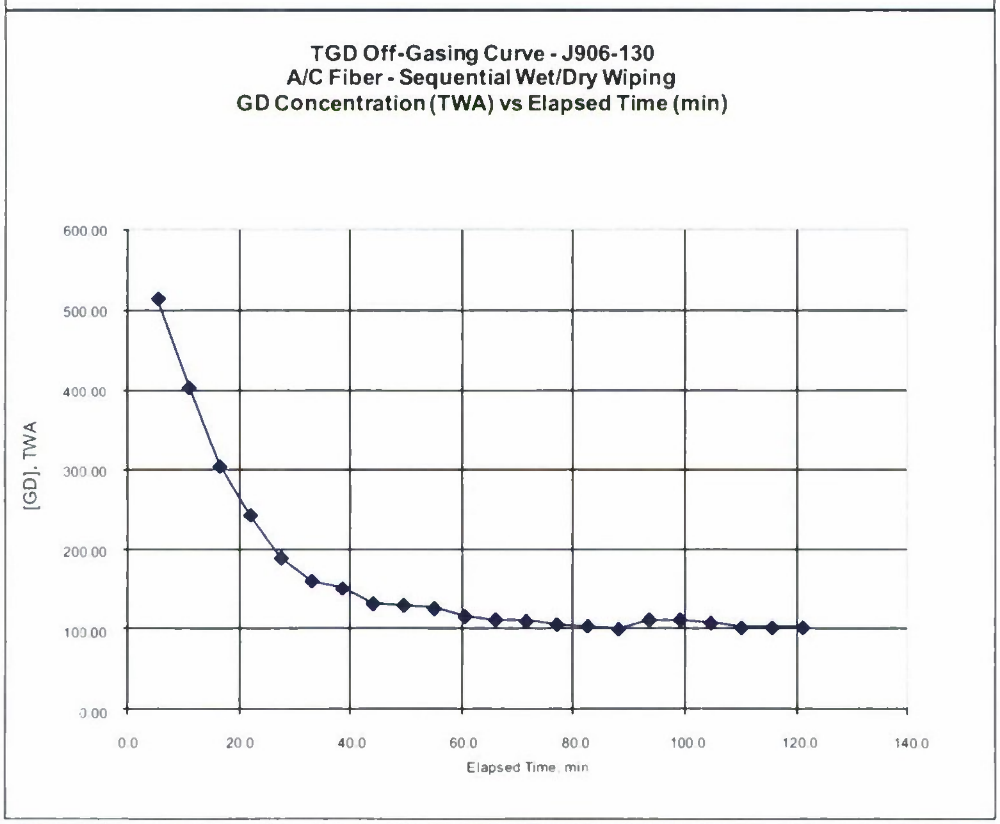
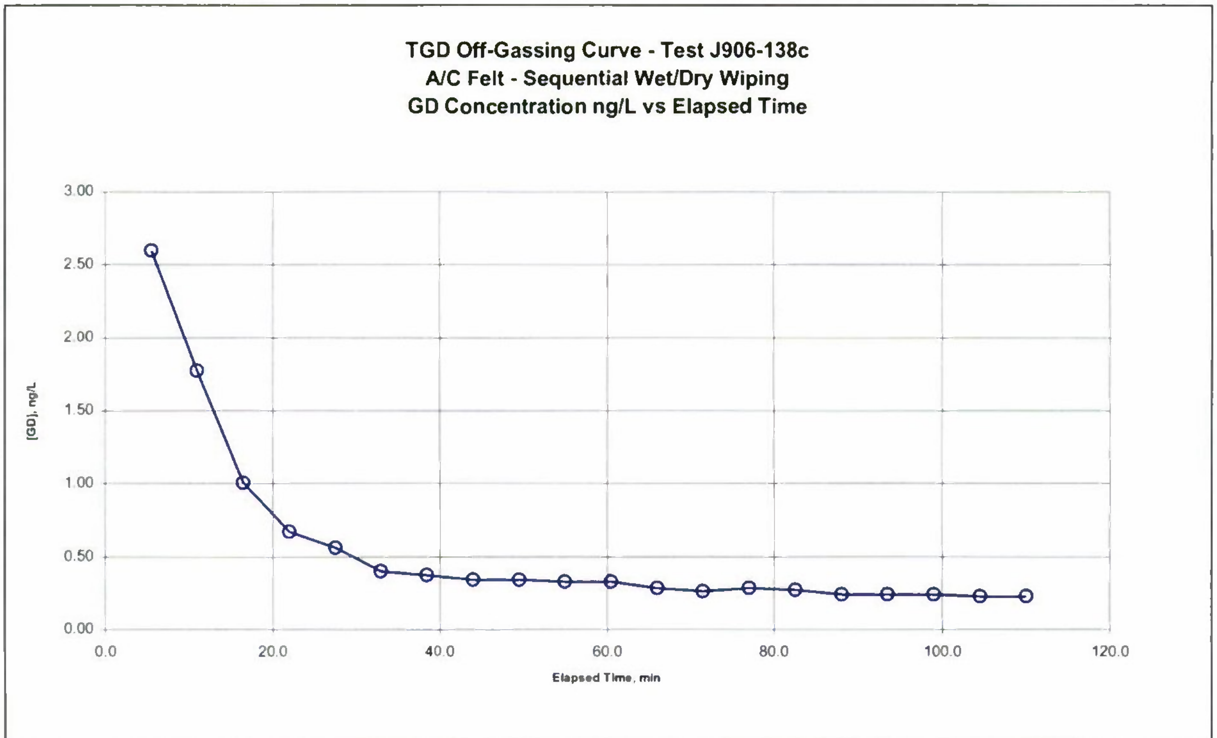


Figure 18. GD vapor off-gas curves from test J906-130. Upper curve: GD concentration vs. time, lower curve: GC off-gassing rate vs. time.



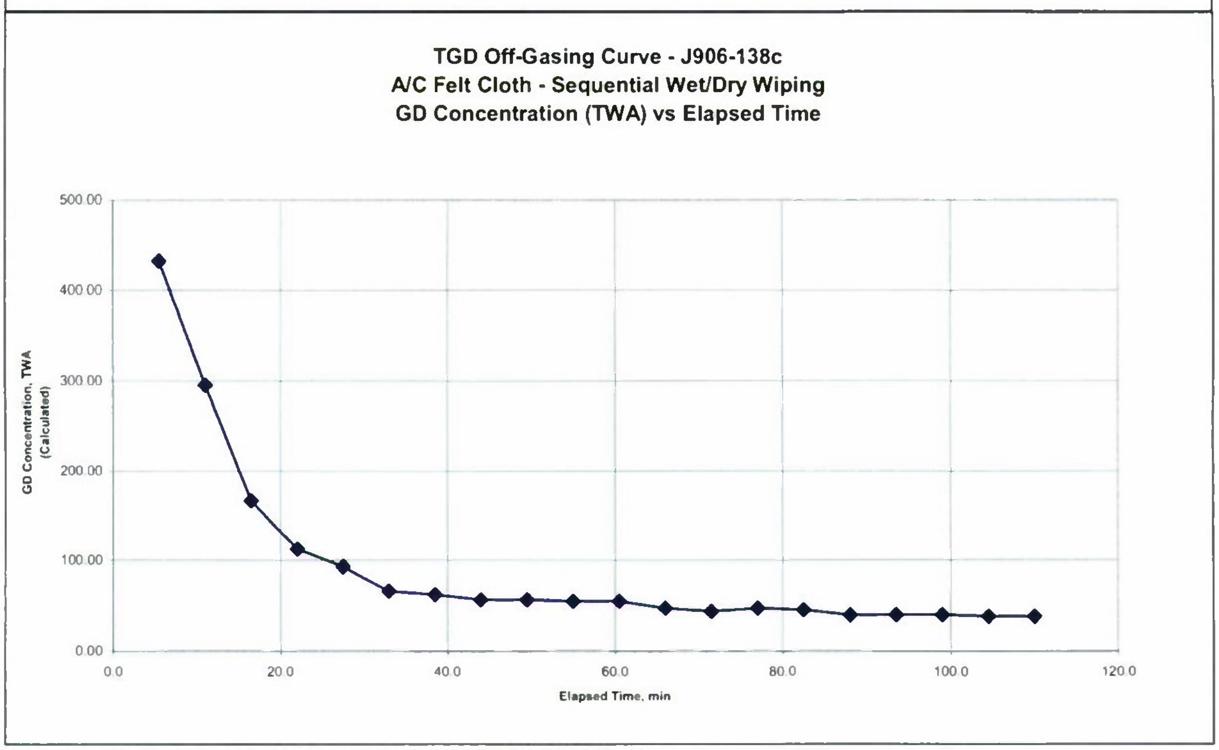
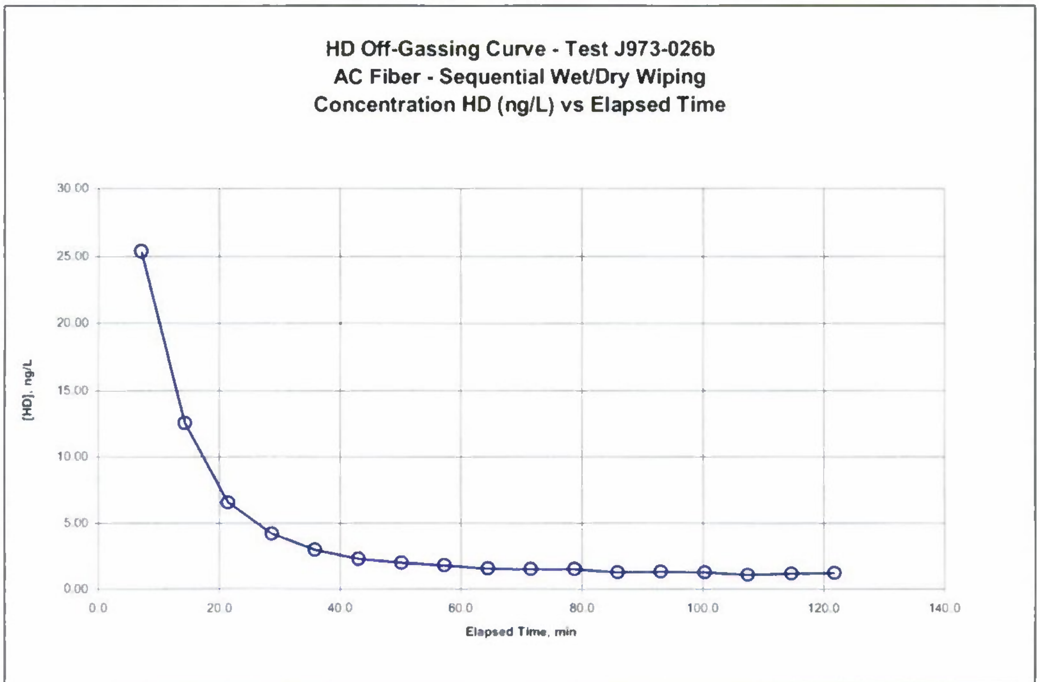


Figure 19. GD vapor off-gas curves from test J906-138(C). Upper curve: GD concentration vs. time, lower curve: GC off-gassing rate vs. time.



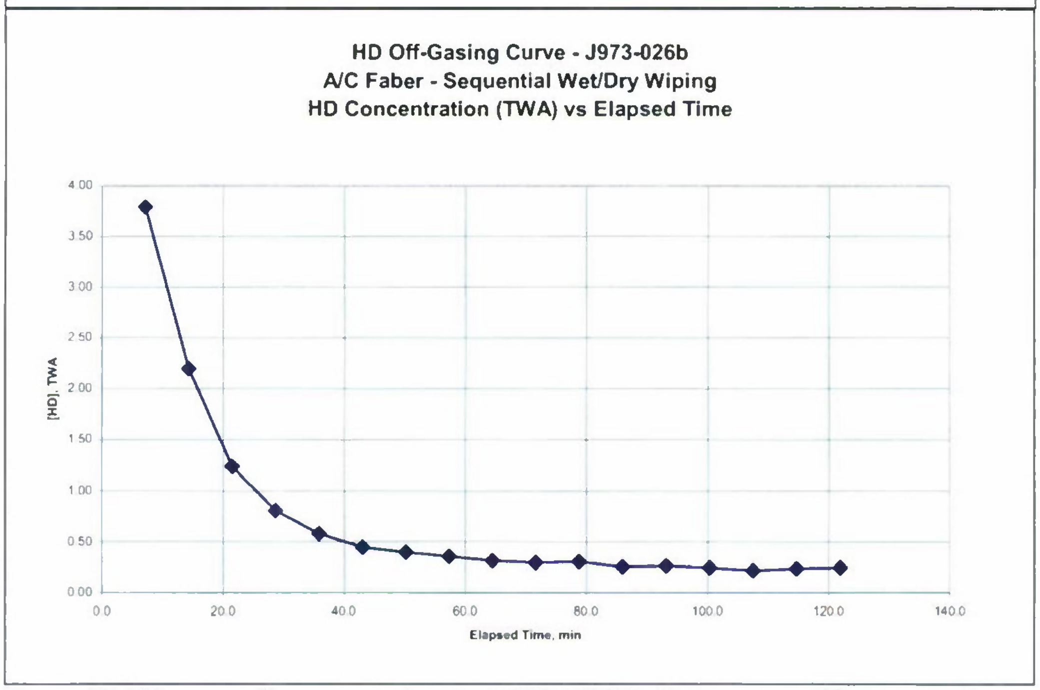


Figure 20. HD vapor off-gas curves from test J906-100(B). Upper curve: GD concentration vs. time lower curve: GC off-gassing rate vs. time

7.6 HD Linear-Wiping Tests on Aluminum

An initial series of 26 HD-wiping tests were conducted on non-absorptive aluminum control surfaces, using the automated linear-wiping test apparatus with KoTHmex AW 1101-activated carbon fabric (A/C Fiber), KoTHmex AM 1132-activated carbon felt (A/C Felt), and 3M Scotch-Brite 2021 (Scotch-Brite).

- Half of the tests were conducted with the wiping material moistened with HFE-7200, and the other half were conducted with dry wiping material (no wiping solvent).
- Fourteen tests were conducted with a wiping sequence consisting of six sequential linear wipe passes over the three test coupons in the text fixture (one iteration of the G240 linear-wiping program).
- Nine tests were conducted with a single linear wipe pass over the test coupons (one iteration of the G0 program).
- Three tests were conducted with four consecutive iterations of the G240 linear-wiping program.

The tests with four iterations of the G240 linear-wiping program generated the same "thorough" wipe contact time as three iterations of the G330 rotary-wiping program (48 s).

Four additional sets of HD linear-wiping tests were conducted, under different sets of test conditions and wiping parameters, on aluminum control surfaces. These four sets used the three primary candidates wipe materials—activated carbon fabric, activated carbon felt, and non-adsorptive micro-fiber wipe. The purpose of the tests was to further compare the three primary candidate wipe materials, and to determine the effect of varying the wiping parameters on the decontamination efficacy of the rotary-wiping test system and procedures. The test parameters that were varied in this limited set of additional tests were:

- Wipe speed and contact time
- HD contamination density
- Wiping solvent

7.6.1 Test Procedure

The following test procedure was followed for the linear-wiping tests for HD on aluminum coupons:

(1) Mounting the coupons.

- Three 1.5 x 1.5 in. square aluminum test coupons were placed in the cutout slots in the aluminum baseplate of the linear-wiping device, as shown in the diagram in Figure 21.

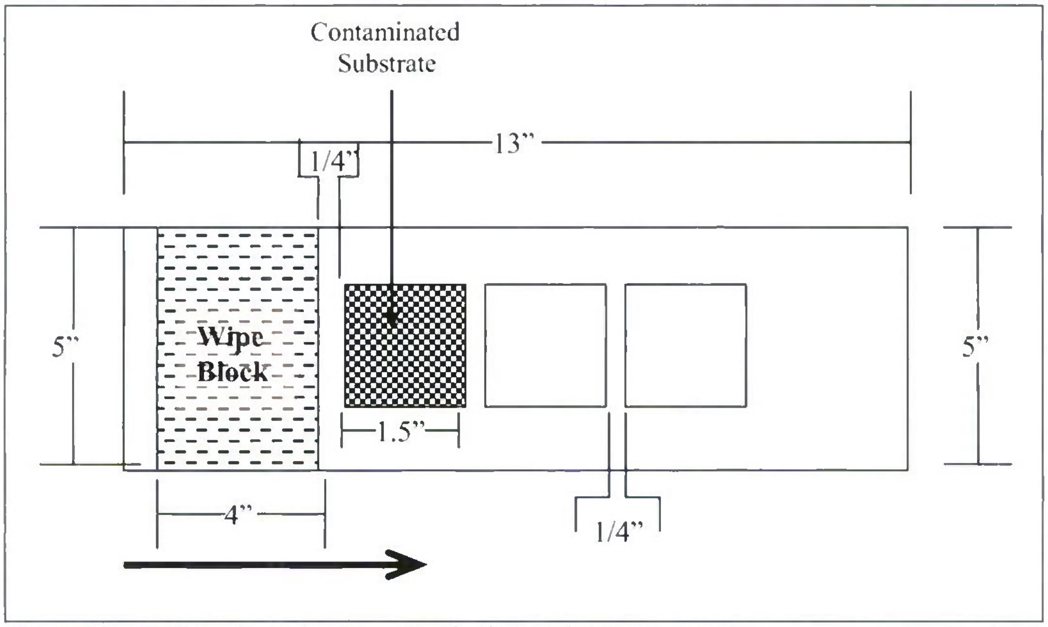


Figure 21. Configuration of test coupons in linear wipe test system.

(2) Attaching the wipe.

- An 8 x 5 in. swatch of wiping material was then cut out and attached to the wiping mandrel. The wiping mandrel was positioned at the far left side of the aluminum baseplate, just to the left of the leftmost aluminum test coupon.

(3) Applying the contaminant.

- The leftmost aluminum test coupon was then uniformly contaminated with 14.5 mg of neat HD, in approximately 2 μL droplets from a microliter syringe, to give an approximate contamination density of 10 g/m^2.

- The other two coupons were not contaminated. (However, the two uncontaminated coupons were wiped, sampled, and analyzed after the completion of the wiping sequence to measure any agent spread from the contaminated coupon by the left to right motion of the wiping block.)

(4) Preparing the wiping mandrel.

- After agent contamination, the wiping mandrel was either left in place on the left side of the aluminum baseplate (in the dry tests with no wiping solvent) or was removed from the baseplate, sprayed with HFE-7200 from a manually air-pressurized Misto olive oil sprayer (to wet the wiping material with HFE-7200 without saturation), and then placed back down on the far left side of the aluminum baseplate. The nylon fishing line was then attached to the two eyelets on the opposite sides of the wiping mandrel, routed through the pulley, wrapped around the motor shaft three times, and tensioned by loosening the wing nut on the pulley, moving the pulley away from the motor until the line is taut, and tightening the wing nut.

- In three of the tests, one test with each of the three wipe materials, after the deposition of the HD droplets on the surface of the leftmost aluminum test coupon, HFE-7200 was sprayed directly onto the HD- contaminated aluminum surface from a manually air-pressurized Misto olive oil sprayer rather than onto the wiping material, and the sprayed, contaminated surface was wiped with a dry wipe. The amount of HFE-7200 sprayed onto the HD contaminated surface was not quantified, but was sufficient to visually wet the contaminated surface with HFE-7200.

(5) Initiating the wiping sequence.

- After completing the previous steps, either a single G240 wiping sequence or a single G0 wiping sequence was initiated from the keyboard of the control computer.

- The G240 linear-wiping program consisted of six sequential linear wipe passes over the test coupons: (1) a left-to-right pass, (2) a right-to-left return pass, (3) a second left-to-right pass, (4) a second right-to-left return pass, (5) a third left-to-right pass, and (6) a third right-to-left return pass. The duration of each pass was 2.0 s, and the weight of the wiping mandrel was 631g (no added weight).

- The G0 linear-wiping program consisted of a single left-to-right pass over the three test coupons. The duration of the pass was 0.5 s. (Note: The weight of the wiping block was weighed on a calibrated balance and was found to be 631 g.)

After the wiping procedure was complete, the amount of residual agent on each test coupon was determined either by solvent extraction and GC-FPD analysis or by DAAMS agent vapor sampling and GC-FID analysis:

- Using the extraction procedure, after the wiping procedure, each of the three aluminum test coupons was removed from the aluminum baseplate and placed in a separate jar containing 25 mL of isopropyl alcohol (IPA). Each jar was sealed, and the aluminum test coupon was allowed to soak in the IPA for 120 min, with intermittent swirling, to extract any residual agent on the test coupon into the IPA extraction solvent. After the 120 min extraction period, the IPA extract was analyzed for residual HD by GC-FPD.

- Using the DAAMS procedure, each of the three aluminum test coupons was removed from the aluminum baseplate and placed in a separate glass sampling jar fitted with air inlet and outlet fittings in the cap of the jar. Room air was pumped into and through the jar then through a 3 mm OD Tenax TA DAAMS transfer tube at a flow rate of 50 mL/min for 120 min. The DAAMS transfer tube was then thermally desorbed into an HP 5890 Series II GC equipped with a DAAMS injection port and a flame ionization detector. Prior to the tests, the GC was calibrated. The total amount of HD collected on and desorbed from the DAAMS tube (in ng) was determined directly from GC response of the desorbed DAAMS sample and the HD calibration curve.

7.6.2 Test Results

The results of the initial linear wiping tests with HD are summarized in Table 25. The results of the additional four sets of HD linear-wiping tests are summarized in Table 26 through Table 29 described as follows:

- Table 26. HD Linear-wiping tests on Aluminum Control Surfaces – Single-Pass, Fast Wipe Speed, Indoor (Low) Contamination Density
- Table 27. HD Linear-wiping tests on Aluminum Control Surfaces – Multiple-Pass, Slow Wipe Speed, Indoor (Low) Contamination Density
- Table 28. HD Linear-wiping tests on Aluminum Control Surfaces – Single-Pass, Slow Wipe Speed, Indoor (Low) Contamination Density
- Table 29. HD Linear-wiping tests on Aluminum Control Surfaces – Single-Pass, Slow Wipe Speed, Outdoor (High) Contamination Density – Wiping Solvent Comparison

Table 25. Results of HD-wiping tests with automated linear-wiping device on non-absorptive aluminum control surfaces.

Test Conditions: Total Mandrel Weight - 631
Single and multiple pass wipes
Wiping Programs – 1 x G0, 1 x G240, 4 x G240
Three test coupons arranged left to right
Only leftmost coupon contaminated with HD
HD contamination density – 10 g/m2

Wiping Material	Solvent/ Decon	Test No.	Sampling Method	HD Contamination Amount mg	Wipe Contact Time s	HD Recovered from Left Coupon µg	HD Recovered From Center Coupon µg	HD Recovered From Right Coupon µg	Total HD Recovery µg	Left Coupon Decon Efficacy %	Total Decon Efficacy %
AC Fabric	HFE-7200	J973-114	Extraction GC-FPD	14.5	12	ND (1)	8.3	ND (1)	≥8.3	99.94	≤99.94
AC Fabric	HFE-7200	J973-126	Extraction GC-FPD	14.5	12	93	72	ND (2)	≥165	99.36	≤98.86
AC Fabric	HFE-7200	J973-156	DAAMS GC-FID	14.5	12	31.6	3.7	1.7	37	99.78	99.75
AC Fabric	None (Dry)	J973-132	Extraction GC-FPD	14.5	12	ND (2)	ND (2)	ND (2)	≥10	≤99.93	≤99.93
AC Fabric	None (Dry)	J973-120	Extraction GC-FPD	14.5	12	ND (1)	ND (1)	ND (1)	≥6	≤99.96	≤99.96
AC Fabric	None (Dry)	J973-146	DAAMS GC-FID	14.5	12	1.5	5.3	1.0	7.8	99.99	99.95
AC Fabric	HFE-7200	J973-148	Extraction GC-FPD	14.5	0.5	186	169	44	399	98.72	97.25
AC Fabric	None (Dry)	J973-140	Extraction GC-FPD	14.5	0.5	121	7.7	ND (1)	≥129	99.17	≤99.11
AC Fabric	Dry Wipe; HFE-7200 on Coupon	J1073-004	Extraction GC-FPD	14.5	0.5	1720	75	ND (2)	≥1795	88.14	≤87.62
AC Fabric	HFE-7200	J1073-014	Extraction GC-FPD	14.5	48	4.7	ND (3)	ND (3)	≥4.7	99.97	99.96
AC Felt	HFE-7200	J973-116	Extraction GC-FPD	14.5	12	960	1030	560	2550	93.38	82.41
AC Felt	HFE-7200	J973-128	Extraction GC-FPD	14.5	12	249	259	94	673	98.28	95.36
AC Felt	HFE-7200	J973-152	Extraction GC-FPD	14.5	0.5	898	2001	883	3782	93.81	73.92
AC Felt	None (Dry)	J973-122	Extraction GC-FPD	14.5	12	61	40	16	117	99.58	98.83
AC Felt	None (Dry)	J973-134	Extraction GC-FPD	14.5	12	57	38	32	127	99.61	99.12
AC Felt	None (Dry)	J973-142	Extraction GC-FPD	14.5	0.5	463	1441	811	2715	96.81	81.28
AC Felt	Dry Wipe; HFE-7200 on Coupon	J1073-008	Extraction GC-FPD	14.5	0.5	839	930	756	2525	94.21	82.59
AC Felt	HFE-7200	J1073-018	Extraction GC-FPD	14.5	48	15	74	18	107	99.90	99.26

Table 25. Results of HD-wiping tests with automated linear-wiping device on non-absorptive aluminum control surfaces (continued).

Wiping Material	Solvent/Decon	Test No.	Sampling Method	HD Contamination Amount mg	Wipe Contact Time s	HD Recovered from Left Coupon µg	HD Recovered From Center Coupon µg	HD Recovered From Right Coupon µg	Total HD Recovery µg	Left Coupon Decon Efficacy %	Total Decon Efficacy %
Scotch-Brite	HFE-7200	J973-118	Extraction GC-FPD	14.5	12	250	69	9	328	98.28	97.74
Scotch-Brite	HFE-7200	J973-130	Extraction GC-FPD	14.5	12	87	73	43	203	99.40	98.60
Scotch-Brite	HFE-7200	J973-150	Extraction GC-FPD	14.5	0.5	270	173	40	483	98.14	96.67
Scotch-Brite	None (Dry)	J973-124	Extraction GC-FPD	14.5	12	38	62	ND (1)	100	99.74	≤99.31
Scotch-Brite	None (Dry)	J973-136	Extraction GC-FPD	14.5	12	14.5	ND (2)	ND (2)	≥15	99.90	≤99.89
Scotch-Brite	None (Dry)	J973-144	Extraction GC-FPD	14.5	0.5	150	142	16	308	98.97	97.87
Scotch-Brite	Dry Wipe; HFE-7200 on Coupon	J1073-006	Extraction GC-FPD	14.5	0.5	60	14	ND (2)	≥74	99.59	≤99.49
Scotch-Brite	HFE-7200	J1073-016	Extraction GC-FPD	14.5	48	4.1	ND (3)	ND (3)	≥4.1	99.97	≤99.97

AC Fabric = KoTHmex AW 1101-activated carbon fabric.
AC Felt = KoTHmex AM 1132-activated carbon felt.
Scotch-Brite = 3M Scotch-Brite 2021

Wiping Program – 1 x G240
Wipe Speed – 2.0 s/pass
No. of Passes – 6
Wipe Contact Time – 12 s

Wiping Program – 4 x G240
Wipe Speed – 2.0 s/pass
No. of Passes – 24
Wipe Contact Time – 48 s

Wiping Program – 1 x G0
Wipe Speed – 0.5 s/pass
Number of Passes – 1
Wipe Contact Time – 0.5 s

(1) ND = None Detected (Estimated detection limit = 6 µg HD)
(2) ND = None Detected (Estimated detection limit = 10 µg HD)
(3) ND = None Detected (Estimated detection limit = 4 µg HD)

Table 26. Summary of HD-wiping tests on aluminum control surfaces with linear wipe test apparatus.

Single-Pass, Fast Wipe Speed, Indoor (Low) Contamination Density

Test Conditions:
Single pass wipe from left to right
Wiping Program – 1 x G0
Wipe Speed – 0.5 s (fast)
Three test coupons arranged left to right
Only leftmost coupon contaminated with HD
Low (indoor) HD contamination density – 1.0 g/m2
Total Mandrel Weight – 631 g
Comparison of dry wipes with wipes wet with HFE-7200

Wiping Material	Solvent/Decon	Test No.	Sampling Method	HD Contam. Amount mg	Wipe Contact Time s	HD Recovered From Left Coupon µg	HD Recovered From Center Coupon µg	HD Recovered From Right Coupon µg	Total HD Recovery µg	Left Coupon Decon Efficacy %	Total Decon Efficacy %
AC Fabric	None (Dry)	J1073 -022	DAAMS GC-FID	1.45	0.5	129.799 (outside upper cal curve limit)	0.351	0.084	130	91.05	91.03
AC Fabric	None (Dry)	J1073 -026	Extraction -GC – Coupon 1 DAAMS-FID – Coupons 2 & 3	1.45	0.5	199	0.348	0.128	199	86.28	86.28
AC Fabric	HFE-7200	J1073 -028	Extraction -GC – Coupon 1 DAAMS-FID – Coupons 2 & 3	1.45	0.5	96.35	0.173	0.060	97	93.36	93.3
Scotch-Brite	None (Dry)	J1073 -032	Extraction GC-FPD	1.45	0.5	58.7	10.5	ND	≥69	95.95	≤95.2
Scotch-Brite	HFE-7200	J1073 -034	Extraction GC-FPD	1.45	0.5	41.5	30.8	4.4	77	97.17	94.7
AC Felt	None (Dry)	J1073 -038	Extraction GC-FPD	1.45	0.5	165	323	23	512	88.62	64.7
AC Felt	HFE-7200	J1073 -040	Extraction GC-FPD	1.45	0.5	200	345	6	552	86.21	61.9

AC Fabric = KoTHmex AW 1101-activated carbon fabric.
AC Felt = KoTHmex AM 1132-activated carbon felt.
Scotch-Brite = 3M Scotch-Brite 2021

ND = None Detected (Estimated detection limit = 2 µg HD)

Table 27. Summary of HD-wiping tests on aluminum control surfaces with linear wipe test apparatus multiple-pass, slow wipe speed, indoor (low) contamination density.

Test Conditions:
Multiple passes to simulate thorough wiping
(linear wipe contact time same as "thorough" rotary-wiping contact time – 48 s)
24 forward-followed-by-reverse passes
Wiping Program – 4 x G240
Wipe Speed – 2 s per pass (slow)
Three test coupons arranged left to right
Only leftmost coupon contaminated with HD
High (outdoor) HD contamination density – 10 g/m2
Total Mandrel Weight – 631 g
Dry wipes only (no HFE-7200) to evaluate comparative wiping ability of the three candidate wipes

Wiping Material	Solvent/Decon	Test No.	Sampling Method	HD Contam. Amount mg	Wipe Contact Time s	HD Recovered From Left Coupon µg	HD Recovered From Center Coupon µg	HD Recovered From Right Coupon µg	Total HD Recovery µg	Left Coupon Decon Efficacy %	Total Decon Efficacy %
AC Fabric	None (Dry)	J1073-042	Extraction GC-FPD	14.5	48	2.9	2.8	ND	≥5.7	99.98	≤99.96
Scotch-Brite	None (Dry)	J1073-044	Extraction GC-FPD	14.5	48	72	8	ND	≥80	99.50	≤99.45
AC Felt	None (Dry)	J1073-046	Extraction GC-FPD	14.5	48	24	31	121	176	99.83	98.79

AC Fabric = KoTHmex AW 1101-activated carbon fabric.
AC Felt = KoTHmex AM 1132-activated carbon felt.
Scotch-Brite = 3M Scotch-Brite 2021

ND = None Detected (Estimated detection limit = 2 µg HD)

Table 28. Summary of HD-wiping tests on aluminum control surfaces with linear wipe test apparatus.

Single-Pass, Slow Wipe Speed, Indoor (Low) Contamination Density

Test Conditions:
Single pass wipe from left to right
Wiping Program – 1 x G180
Wipe Speed – 2.0 s (slow)
Three test coupons arranged left to right
Only leftmost coupon contaminated with HD
Low (indoor) HD contamination density – 1.0 g/m2
Total Mandrel Weight – 631 g
Comparison of dry wipes with wipes wet with HFE-7200 at the slow wipe speed

Wiping Material	Solvent/Decon	Test No.	Sampling Method	HD Contam. Amount Mg	Wipe Contact Time s	HD Recovered From Left Coupon µg	HD Recovered From Center Coupon µg	HD Recovered From Right Coupon µg	Total HD Recovery µg	Left Coupon Decon Efficacy %	Total Decon Efficacy %
AC Fabric	HFE-7200	J1073-048	Extraction GC-FPD	1.45	2.0	ND	ND	ND	≥2	≥99.86	≤99.86
AC Fabric	None (Dry)	J1073-050	Extraction GC-FPD	1.45	2.0	41	ND	ND	≥41	97.24	≤97.24
Scotch-Brite	None (Dry)	J1073-054	Extraction GC-FPD	1.45	2.0	ND	27	3	≥30	≥99.86	≤97.93
Scotch-Brite	HFE-7200	J1073-056	Extraction GC-FPD	1.45	2.0	60	26	3	89	95.86	93.86
AC Felt	None (Dry)	J1073-058	Extraction GC-FPD	1.45	2.0	126	238	52	416	91.31	71.31
AC Felt	HFE-7200	J1073-060	Extraction GC-FPD	1.45	2.0	172	409	52	633	88.14	56.34

AC Fabric = KoTHmex AW 1101-activated carbon fabric.
AC Felt = KoTHmex AM 1132-activated carbon felt.
Scotch-Brite = 3M Scotch-Brite 2021

ND = None Detected (Estimated detection limit = 2 µg HD)

Table 29. Summary of HD-wiping tests on aluminum control surfaces with linear wipe test apparatus.

Single-Pass, Slow Wipe Speed, Indoor (Low) Contamination Density

Test Conditions:
Single pass wipe from left to right
Wiping Program – 1 x G180
Wipe Speed – 2.0 s (slow)
Wipe Contact Time – 2.0 s
Three test coupons arranged left to right
Only leftmost coupon contaminated with HD
High (outdoor) HD contamination density – 10 g/m2
Total Mandrel Weight – 631 g

Wiping Material	Solvent/Decon	Test No.	Sampling Method	HD Contam. Amount mg	Wipe Contact Time s	HD Recovered From Left Coupon µg	HD Recovered From Center Coupon µg	HD Recovered From Right Coupon µg	Total HD Recovery µg	Left Coupon Decon Efficacy %	Total Decon Efficacy %
AC Fabric	IPA	J1073-064	Extraction GC-FPD	14.5	2.0	ND	ND	ND	≥4	≥99.97	≤99.97
AC Fabric	IPA	J1073-066	Extraction GC-FPD	14.5	2.0	5	ND	ND	≥5	99.97	≤99.97
AC Felt	IPA	J1073-068	Extraction GC-FPD	14.5	2.0	11	21	49	81	99.92	99.44
AC Felt	IPA	J1073-070	Extraction GC-FPD	14.5	2.0	185	181	36	401	98.72	97.23
AC Fabric	Hexane	J1073-074	Extraction GC-FPD	14.5	2.0	79	35	4	118	99.46	99.19
AC Fabric	Hexane	J1073-076	Extraction GC-FPD	14.5	2.0	222	10	ND	≥232	98.47	≤98.40
AC Felt	Hexane	J1073-078	Extraction GC-FPD	14.5	2.0	308	89	22	419	97.88	97.11
AC Felt	Hexane	J1073-080	Extraction GC-FPD	14.5	2.0	174	83	15	272	98.80	98.12
AC Fabric	HFE-7200	J1190-044	Extraction GC-FPD	14.5	2.0	198	112	ND	≥310	98.63	≤97.86
AC Fabric	HFE-7200	J1190-045	Extraction GC-FPD	14.5	2.0	124	ND	ND	≥124	99.15	≤99.15
AC Felt	HFE-7200	J1190-042	Extraction GC-FPD	14.5	2.0	593	1314	382	2289	95.91	84.21
AC Felt	HFE-7200	J1190-043	Extraction GC-FPD	14.5	2.0	310	766	352	1428	97.86	90.15

AC Fabric = KoTHmex AW 1101-activated carbon fabric.
AC Felt = KoTHmex AM 1132-activated carbon felt.
ND = None Detected (Estimated detection limit in IPA and hexane tests = 4 µg HD)
ND = None Detected (Estimated detection limit in HFE-7200 tests = 20 µg HD)

7.6.3 Discussion of Results

7.6.3.1 Type of Wipe

As can be seen from the total residual HD recoveries and decontamination efficacies in Table 26 through Table 29, and in summary Table 30 below, in the tests with HFE-7200, the KoTHmex AW 1101-activated carbon fabric was the most effective wipe material in removing HD from the aluminum control coupon. This was followed by the 3M Scotch-Brite 2021 and then the KoTHmex AM 1132-activated carbon felt. The activated carbon felt was much less effective in the linear wiping tests than it was in the rotary-wiping tests. The reason for the relatively worse performance of the activated carbon felt wipes in the linear wiping tests may be related to (1) the shorter contact time between the felt and the agent-contaminated surface during the linear tests (relative to the rotary tests), (2) the rate of HD adsorption onto the activated carbon felt, and (3) the HD transport into the interior of the felt wipe and away from the surface of the wipe.

The HD decontamination efficacies with all three wiping materials were greater with the dry wipes than with the wipes that were wet with HFE-7200. While the differences in the wet and dry decontamination efficacies were generally not great, the trend was seen in the tests with one iteration of the G240 program, one iteration of the G0 program, and with both DAAMS sampling and analysis and with solvent extraction and GC analysis.

Table 30. Summary of HD Linear-wiping tests (From Data in Tables 24, 26, and 28).

Wiping Material	HD Contamination Density g/m^2	Number of Wipe Passes	Wipe Contact Time s	Total Decontamination Efficacy%		
				HFE-7200	Dry (No Solvent)	HFE-7200 Spray+ Dry Wipe
AC Fabric	10	1	0.5	97.25	99.11	87.62
AC Fabric	10	1	2.0	98.50	-	-
AC Fabric	10	6	12	99.52	99.95	-
AC Fabric	10	24	48	99.96	-	-
AC Felt	10	1	0.5	73.92	81.28	82.59
Ac Felt	10	1	2.0	87.18	-	-
AC Felt	10	6	12	88.89	98.98	-
AC Felt	10	24	48	99.03	-	-
Scotch-Brite	10	1	0.5	96.67	97.87	99.49
Scotch-Brite	10	1	2.0	-	-	-
Scotch-Brite	10	6	12	98.17	99.60	-
Scotch-Brite	10	24	48	99.71	-	-

7.6.3.2 Number of Wipe Passes/Wipe Contact Time

As shown in Table 30 above, the HD decontamination efficacy for each wipe material increases with the number of wipe passes and wipe contact time, whether with wipe is solvent-moistened or dry. In very limited single-pass testing, the HD decontamination efficacy increased with a decrease in wiping speed (in going from a wipe speed of 2 to 0.5 s/pass). These observations, however, are based on a limited number of replicate tests, and additional testing is needed.

7.6.3.3 Wet Wipe vs. Dry Wipe vs. Spray-and-Wipe

Three tests were conducted in which HFE-7200 was sprayed directly onto the HD-contaminated surface of the leftmost aluminum tests coupon, followed by the wiping of the surface with a dry wipe. One test was conducted with each wipe material. The HD decontamination efficacy was poorer in the spray and wipe test with activated carbon fabric, than in the tests with either dry or HFE-7200-moistened AC fabric. In the tests with activated carbon felt, there was no significant difference between the HD decontamination efficacy in the spray and wipe test and the efficiencies in the dry or pre-moistened wipe tests. And in the tests with Scotch-Brite wipes, the HD removal efficiency was greater in the spray and wipe test than in either the dry-wipe or pre-moistened-wipe tests. Since only a single spray and wipe test was conducted with each wipe material, however, no firm conclusions about the relative efficiencies of spray and wipe procedure can be drawn from the test results.

7.6.3.4 Comparison of Wiping Solvents

The results of the tests detailed in Table 30 were conducted specifically to compare the decontamination efficacy of adsorbent wipes moistened with HFE-7200 with the removal efficiencies of the same wipe materials moistened with the more-HD-soluble solvents hexane and isopropyl alcohol (IPA). As summarized in Table 31, of the three wipe solvents evaluated, IPA was the most effective solvent in the surface removal of HD, followed by hexane, and then HFE-7200, with both the activated carbon fabric and the activated carbon felt wipe materials.

- With the AC fabric wipes, the differences in HD surface-removal efficiencies among the three solvents were small.
- With the AC felt wipes, the HD-surface-removal efficiency with HFE-7200 was significantly less than the corresponding efficiencies with IPA and hexane. The reason for this is not readily apparent.

Table 31. Comparison of wiping solvents.

Solvent	Total HD Decontamination Efficacy	
	AC Fabric	AC Felt
IPA	99.97 %	98.34 %
Hexane	98.80 %	97.62 %
HFE-7200	98.51 %	85.68 %

Using all three solvents, the HD surface-removal efficiencies of the AC carbon fabric wipes were greater than those of the AC carbon felt wipes.

7.6.3.5 Agent Spreading

Although decontamination of the HD-contaminated coupon (the leftmost coupon) is the result of primary interest, the linear-wiping tests with HD confirmed the ESI findings with agent simulants that the linear-wiping procedure spread the agent contamination from the contaminated aluminum coupon to the other two aluminum coupons. The extent and distribution of the spreading appeared to be highly dependent upon the wiping material and the material's efficiency in removing HD from a contaminated surface, especially in the single-pass tests.

The distribution of HD spreading in the single-pass linear-wiping tests is shown for each of the three wiping materials evaluated in the stacked-column bar charts in Figure . Figure a shows the agent spreading results with activated carbon fabric wipes, Figure b the results with activated carbon felt wipes, and Figure c the results with Scotch-Brite wipes.

Each bar in the chart illustrates the fraction of residual HD found on each of the three test coupons in a given test.

- The blue-colored portion of the bar represents the percent of total residual HD found on the leftmost (contaminated) coupon.
- The violet-colored portion of the bar represents the percent of total residual HD found on the center coupon.
- The cream-colored portion of the bar represents the percent of total residual HD found on the rightmost coupon.

Overall, the least amount of agent spreading was seen in the tests with activated carbon fabric wipes, and the greatest amount of spreading was seen in the tests with activated carbon felt.

In the tests with activated carbon fabric wipes and Scotch-Brite wipes, greater than 50% of the residual HD was found on the leftmost (contaminated) coupon in all but one of the tests. In most of the tests, much greater than 50% of the total residual HD was found on the leftmost coupon. The bulk of the agent that had been spread from the contaminated coupon was found on the coupon immediately adjacent to the contaminated coupon (i.e., on the center coupon).

In most of the tests with activated carbon felt wipes, the residual HD was more uniformly distributed over the three coupons, with the bulk of the residual agent found on the center coupon. Greater than 50% of the total residual HD was found on the center coupon in all but the spray and wipe test, with about 20–30% on the leftmost (contaminated) coupon and 20–30% on the rightmost coupon.

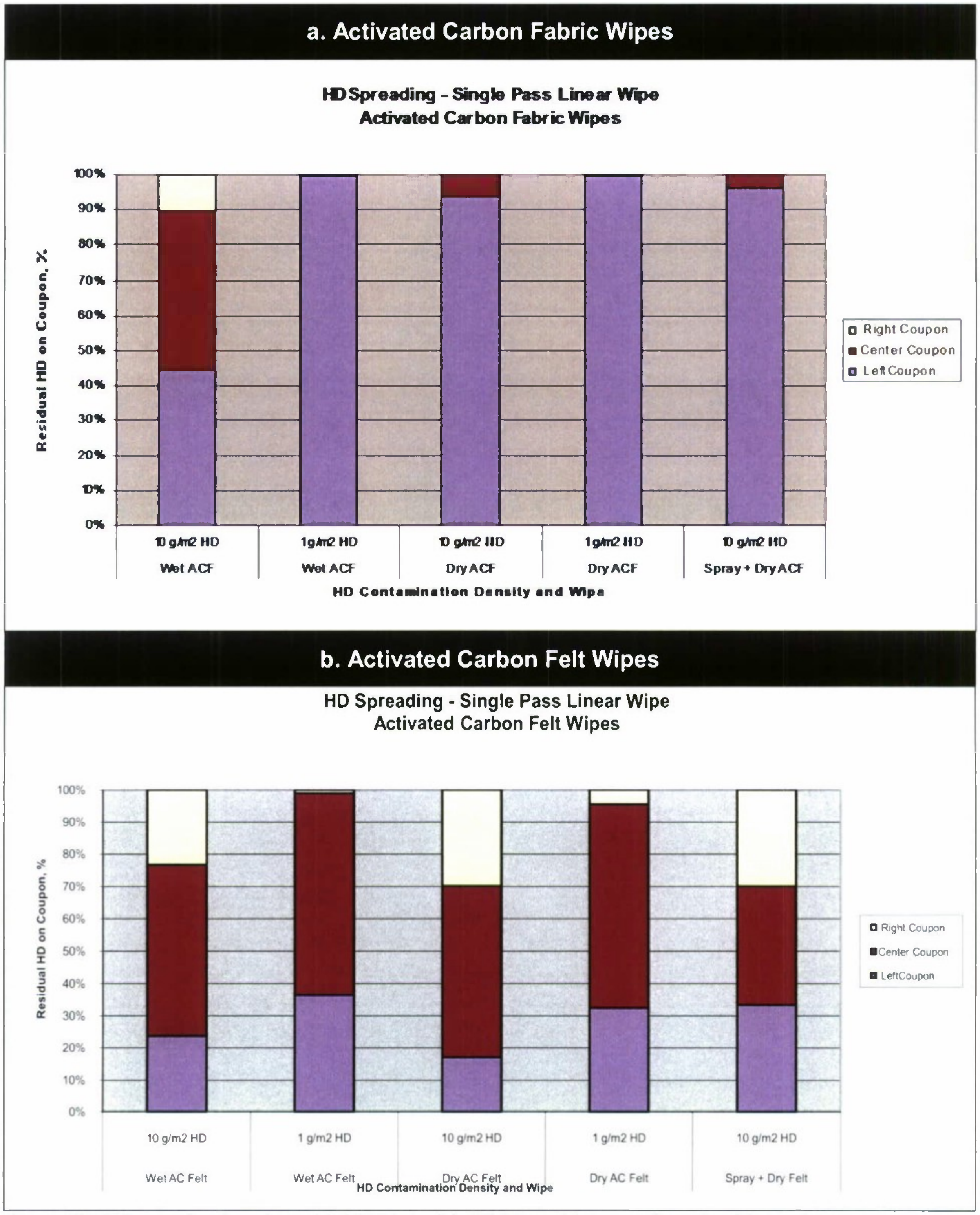


Figure 22. HD-spreading bar charts (a) AC fabric, (b) AC felt, and (c) non-adsorptive fabric wipes.

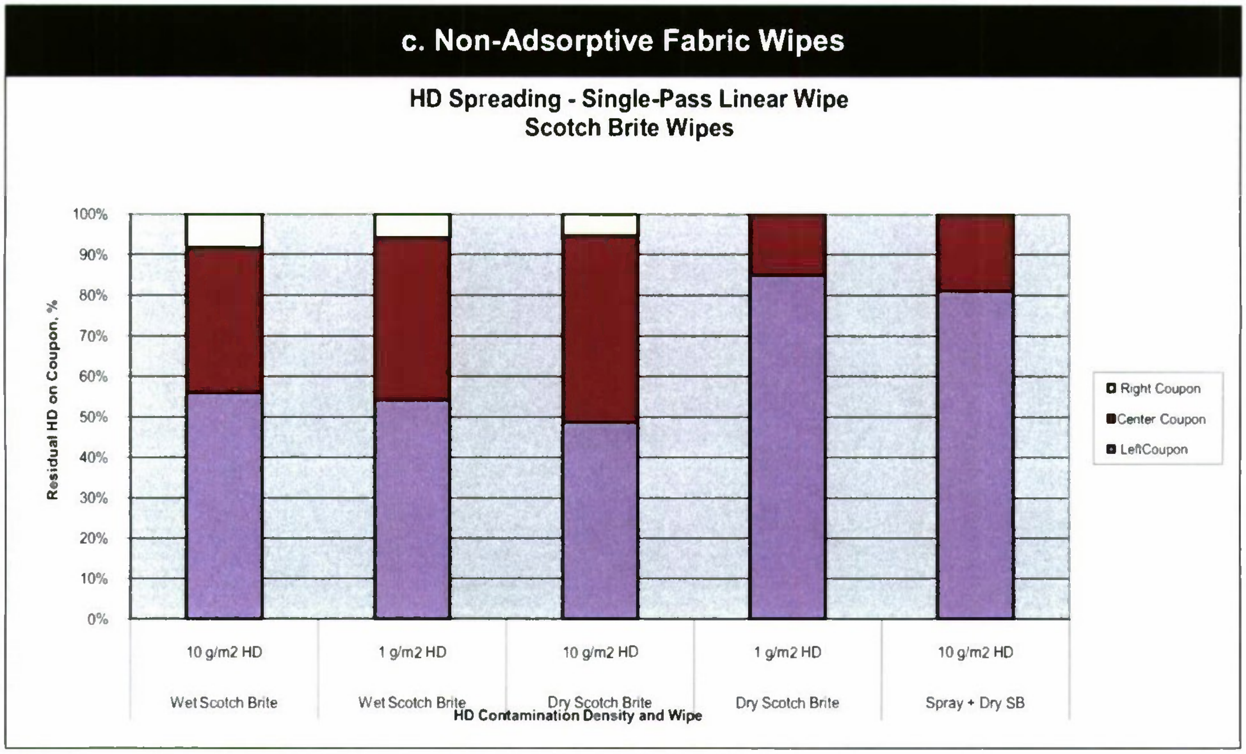


Figure 22. HD-spreading bar charts (a) AC fabric, (b) AC felt, and (c) non-adsorptive fabric wipes (continued).

7.7 HD Rotary and Linear-Wiping Tests on Absorptive Test Surfaces

Automated HD rotary- and linear-wiping tests were conducted on a set of absorptive test surfaces—CARC-painted and alkyd-painted stainless steel test coupons provided by the Government, and polycarbonate and high-density-polyethylene (HDPE) coupons that were purchased commercially.

The dimensions of the CARC- and alkyd-painted panels (2 x 2 in. square x 0.125 in. thick) were different from the dimensions of the aluminum test coupons that had been used in all of the previous tests (1.5. x 1.5 in. square x 0.25 in. thick). The HDPE and polycarbonate test coupons were custom cut to the same dimensions as the CARC- and alkyd-painted panels.

As described previously, in order to conduct the tests with the 2 x 2 in. square x 0.125 in. thick test coupons, an additional set of baseplates (one for the rotary-wiping test apparatus and one for the linear wipe test apparatus) were designed and fabricated. The baseplates were needed to accommodate the thinner, larger-footprint test coupons. Each of the additional baseplates was fabricated with a single cutout (instead of the three cutouts in the baseplate of the linear-wiping test apparatus).

7.7.1 HD Rotary-Wiping Tests on CARC and Alkyd Test Surfaces with Activated Carbon Fabric and Felt Wipes Using HFE-7200 Solvent

The initial tests that were conducted on CARC- and alkyd-painted test surfaces were automated HD rotary-wiping tests with activated carbon fabric and activated carbon felt wipes. All but two of the tests were conducted with activated carbon fabric wipes. A preliminary set of HD rotary-wiping tests on non-absorptive aluminum control surfaces were also conducted for comparison. Some of the tests were conducted with a dry wipe, some with a wipe moistened with HFE-7200, and some with an HFE-7200 spray onto the contaminated surface, followed by a dry wipe.

The tests were conducted at room temperature and ambient relative humidity with the automated rotary-wiping device using the general test procedures described in Section 7.2. Each of the HD tests was conducted using the 350 g aluminum rotary-wiping mandrel with no added weight. In each test a single wipe sequence was employed—three iterations of the G330 rotary-wiping program command (24 wipe cycles), giving a total wipe contact time of 48 s.

The following test procedure was followed for the rotary-wiping tests using HD on CARC- and alkyd-painted test coupons:

(1) Mounting the coupons.

- A 1.5 x 1.5 in. square aluminum test coupon or a 2 x 2 in. square x 0.125 in. thick painted stainless steel panel was mounted in the rotary-wiping device.

(2) Applying the contaminant.

- The coupon surface was then uniformly contaminated with either 14.5 mg (in the tests with aluminum surfaces) or 2.6 mg (in the tests with painted surfaces) HD to give a contamination density of 10 g/m^2 in the tests with the aluminum surfaces and 1.0 g/m^2 in the tests with the painted surfaces. (Comparison tests on aluminum control surfaces at a HD contamination density of 1.0 g/m^2 were inadvertently not conducted.) The agent was applied over the coupon surface as approximately 1 μL droplets from a micropipettor.

(3) Attaching the wipe.

- A dry wipe or a wipe wetted with HFE-7200 was attached to the wiping mandrel. Then the mandrel with the wipe was placed on top of the agent-contaminated surface so that the turning pin on the shaft of the stepper motor was positioned in the slotted shaft of the wiping mandrel.

(4) Preparing the wipe.

- In several of the tests, after the HD droplets were deposited on the surface of the test coupon, HFE-7200 was sprayed directly onto the HD- contaminated aluminum surface from a manually air-pressurized Misto olive oil sprayer. The sprayed, contaminated surface was then wiped with either a dry wipe or a wipe moistened with HFE-7200. The amount of HFE-7200 sprayed onto the HD-contaminated surface was not quantified, but was sufficient to visually wet the contaminated surface.

(4) Initiating the wiping sequence.

- Three iterations of the G330-wiping command were then sequentially input to the wiping device from the control PC to simulate thorough wiping (48 s wipe contact time).

After the wiping procedure was complete, the residual HD on each aluminum control surface was determined by either MINICAMS sampling and analysis, DAAMS GC-FID sampling and analysis, or solvent extraction and GC-FPD analysis of the solvent extract, as described in Section 7.5.

Using the extraction procedure, after completing the wiping procedure, the test coupon was removed from the aluminum baseplate and placed in a separate jar containing 25 mL of isopropyl alcohol (in the tests with aluminum coupons) or 50 mL of IPA (in the tests with painted coupons). The jar was sealed, and the test coupon was allowed to soak in the IPA for 120 min with intermittent swirling to extract any residual agent on the test coupon into the IPA extraction solvent. After the 120 min extraction period, the IPA extract was analyzed for residual HD by GC-FPD.

Using the DAAMS procedure, each of the three aluminum test coupons were removed from the aluminum baseplate and placed in a separate glass sampling jar fitted with air inlet and outlet fittings in the cap of the jar. Room air was pumped into and through the jar and then through a 3 mm OD Tenax TA DAAMS transfer tube at a flow rate of 200 mL/min for the following time periods, replacing the DAAMS tube after each time period:

1. First tube 15 min sample period.

2. Second tube 15 min sample period.

3. Third tube 30 min sample period.

4. Fourth tube 30 min sample period.

5. Fifth tube final 30 min sample period.

Five DAAMS tubes were used to sample sequentially at 200 mL/min for a total of 120 min (a total sample volume of 24 L). Prior to the tests the GC was calibrated. The total amount of HD collected on and desorbed from each DAAMS tube (in ng) was determined directly from GC response of the desorbed DAAMS sample and the HD calibration curve.

Using the MINICAMS procedure after the wiping procedure was complete; the wiped test coupon was placed in a glass sampling jar with air inlet and outlet fitting in the cap of the jar. Room air was sampled into and through the jar into a MINICAMS unit. The collected MINICAMS samples were analyzed directed by the MINICAMS. Each jar was sampled and analyzed for residual agent vapor for up to 2 h.

7.7.1.1 Results

The results of the HD rotary-wiping tests with CARC- and alkyl-painted surfaces are summarized in Table 32. Note that the decontamination efficacy results in the right-most column of the table are expressed as room-temperature decontamination efficacies. As discussed in the next section, there is a significant temperature dependence on the recovery of agent from absorptive surfaces by agent-vapor off-gas monitoring techniques.

On the basis of the total residual HD recovered from the test surfaces at room temperature after agent contamination and subsequent wiping, all of the tests with activated carbon fabric with either a dry wipe, an HFE-7200-moistened wipe, or using a spray-and-wipe technique indicated very good HD decontamination efficiencies from the aluminum control surfaces and CARC-painted stainless steel panels, regardless of the type of analysis used for determining the amount of residual agent:

- >99.9% HD removal efficiency from aluminum control surfaces (extraction, MINICAMS, DAAMS)

- >99.9% HD removal efficiency from CARC surface (MINICAMS, DAAMS)

- Approximately 99.4% HD removal efficiency from CARC surface (solvent extraction)

Table 32. Summary of HD rotary-wiping tests with CARC- and alkyl-painted surfaces.

Test Conditions:
Three iterations of the G330 wiping program – 8 clockwise/counterclockwise revolutions to simulate thorough wiping
Wipe Speed – 1 rev/s
Single coupon per test
Both high (outdoor) and low (indoor) HD contamination densities – 10 g/m^2 and 1.0 g/m^2
Three types of sampling and analysis methods evaluated –
MINICAMS, extraction and GC-FPD analysis, and DAAMS GC-FID

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Sampling Method	Total Mandrel Weight g	HD Contamination Density g/m^2	HD Contamination Amount mg	Wipe Contact Time, s	HD Recovered from Coupon µg	Room Temp. Decon Efficacy %
AC Fabric AW1101	Aluminum	Rotary	Wet Wipe (HFE-7200)	J1073-090	MINICAMS	350	10	14.5	48	1.12	99.99
AC Fabric AW1101	Aluminum	Rotary	Wet Wipe (HFE-7200)	J1073-092	MINICAMS	350	10	14.5	48	1.12	99.99
AC Fabric AW1101	Aluminum	Rotary	Wet Wipe (HFE-7200)	J1073-104	Extraction/GC-FPD	350	10	14.5	48	3.41	99.98
AC Fabric AW1101	CARC	Rotary	Wet Wipe (HFE-7200)	J1073-110	MINICAMS	350	1	2.6	48	1.39	99.95*
AC Fabric AW1101	CARC	Rotary	Wet Wipe (HFE-7200)	J1073-114	MINICAMS	350	1	2.6	48	Peaks off scale	Not quantifiable
AC Fabric AW1101	CARC	Rotary	Wet Wipe (HFE-7200)	J1073-096	Extraction/GC-FPD	350	10	2.6	48	192	99.26
AC Fabric AW1101	CARC	Rotary	Wet Wipe (HFE-7200)	J1073-098	Extraction/GC-FPD	350	0 – Control	0	48	0.000	NA
AC Fabric AW1101	CARC	Rotary	Wet Wipe (HFE-7200)	J1073-108	Extraction/GC-FPD	350	1	2.6	48	15.3	99.42
AC Fabric AW1101	CARC	Rotary	Wet Wipe (HFE-7200)	J1073-122	DAAMS/GC-FID	350	1	2.6	48	2.25	99.91*
AC Fabric AW1101	CARC	Rotary	Dry wipe	J1073-126	DAAMS/GC-FID	350	1	2.6	48	2.09	99.92*
AC Fabric AW1101	CARC	Rotary	HFE-7200 spray + Wet wipe (HFE-7200)	J1073-120	DAAMS/GC-FID	350	1	2.6	48	0.938	99.96*
AC Fabric AW1101	CARC	Rotary	HFE-7200 spray + Dry wipe	J1073-124	DAAMS/GC-FID	350	1	2.6	48	1.70	99.94*
AC Fabric AW1101	Alkyd	Rotary	Wet Wipe (HFE-7200)	J1073-100	Extraction/GC-FPD	350	0 – Control	0	48	0.000	NA
AC Fabric AW1101	Alkyd	Rotary	Wet Wipe (HFE-7200)	J1073-102	Extraction/GC-FPD	350	10	2.6	48	4459	82.87
AC Fabric AW1101	Alkyd	Rotary	Dry wipe	J1190-004	DAAMS/GC-FID	350	1.0	2.6	48	112	95.68*
AC Fabric AW1101	Alkyd	Rotary	Wet Wipe (HFE-7200)	J1190-005	DAAMS/GC-FID	350	1.0	2.6	48	133	94.89*
AC Felt AM1132	CARC	Rotary	Dry wipe	J1190-010	DAAMS/GC-FID	350	1.0	2.6	48	2.02	99.92*
AC Felt AM1132	CARC	Rotary	Wet Wipe (HFE-7200)	J1190-011	DAAMS/GC-FID	350	1.0	2.6	48	123	95.26*

AC Fabric = KoTHmex AW 1101 or AW 1103 activated carbon fabric.
AC Felt = KoTHmex AM1132-activated carbon felt

As expected, in the tests with alkyl-painted stainless steel coupons, the room-temperature HD decontamination efficacies were lower than in the tests with CARC-painted coupons because of the greater absorption of agent into the alkyd paint. The amount of recovered HD, and the corresponding room-temperature decontamination efficacy, was dependent on the sampling and analysis method used to determine the residual amount of agent on and in the alkyd paint:

- Approximately 95% HD removal efficiency from alkyd surface, as determined by DAAMS GC-FPD sampling and analysis (Test J1190-005)

- Approximately 83% HD removal efficiency from alkyd surface, as determined by solvent extraction and GC-FPD analysis (Test J1073-102).

The DAAMS-FID room temperature vapor off-gas monitoring determined that 133 µg of post-wipe residual HD was recovered from the alkyd-painted test coupon in test number J1190-005. Nearly 4500 µg of residual HD was recovered in test number J1073-102, conducted under the same set of conditions as test J1073-102, except for the use of solvent extraction and GC-FPD analysis to determine the residual HD on the alkyd-painted test coupon. The extraction solvent was able to extract a large amount of HD that was absorbed in the alkyd paint, resulting in lower total room-temperature decontamination efficacies.

In the tests with CARC-painted coupons, in which HD absorption is relatively small, the relative difference in post-wipe HD recovery between vapor off-gas monitoring and solvent extraction/GC-FPD analysis is less significant than in the tests with alkyd-painted coupons, but is still evident from a comparison of the total HD recoveries.

In the limited tests conducted, the activated carbon fabric, whether dry or HFE-7200-moistened, was more generally more effective in removing HD from contaminated CARC-painted stainless steel coupons than the activated carbon felt.

Consistently throughout this set of tests, dry wipes, whether fabric or felt, were as effective as or more effective than HFE-7200-moistened wipes.

7.7.1.2 Temperature Dependence of Off-Gas Monitoring

When MINICAMS sampling and analysis were used to determine the amount of residual HD on the wiped test coupons, test results showed a significant temperature dependence on the recovery of agent from absorptive surfaces by agent-vapor off-gas monitoring techniques.

At room temperature, the HD off-gassing curve from CARC (as shown below in Figure 24 for Test J1073-110 and in Figure 25 for Test J1073-114) is almost is almost identical to the HD off-gassing curve from aluminum (as shown in Figure 23 for Test J1073-092) run under identical conditions. However, as shown in Figure 25, when the off-gassing temperature was increased from ambient (approximately 25 °C) to 50 °C after off-gas monitoring at room temperature for 250 min, a large, but unquantifiable amount of additional HD desorbed and off-gassed from the CARC panel.

Because of time and schedule constraints in the test program, further evaluation and development of a quantitative MINICAMS sampling-and-analysis method for the determination of residual agent off-gassing at elevated temperatures was not able to be conducted.

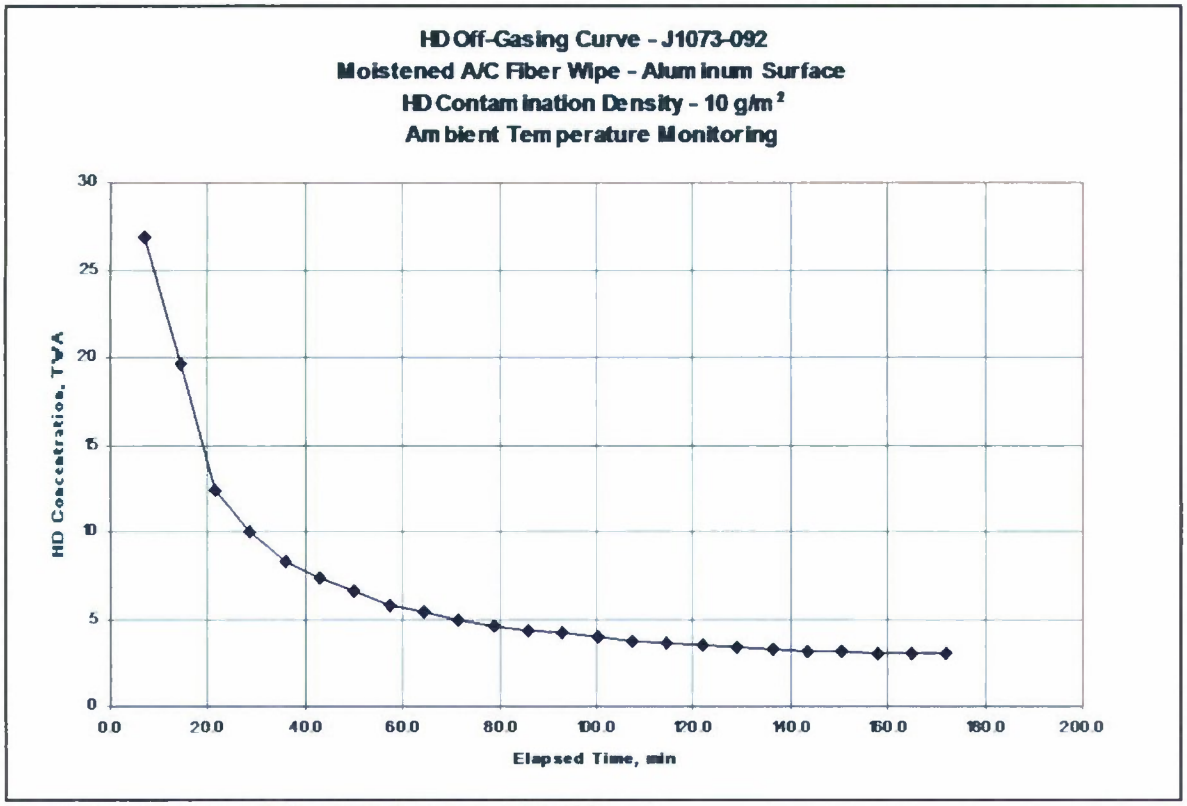


Figure 23. HD vapor off-gas curve from test J1073-092.

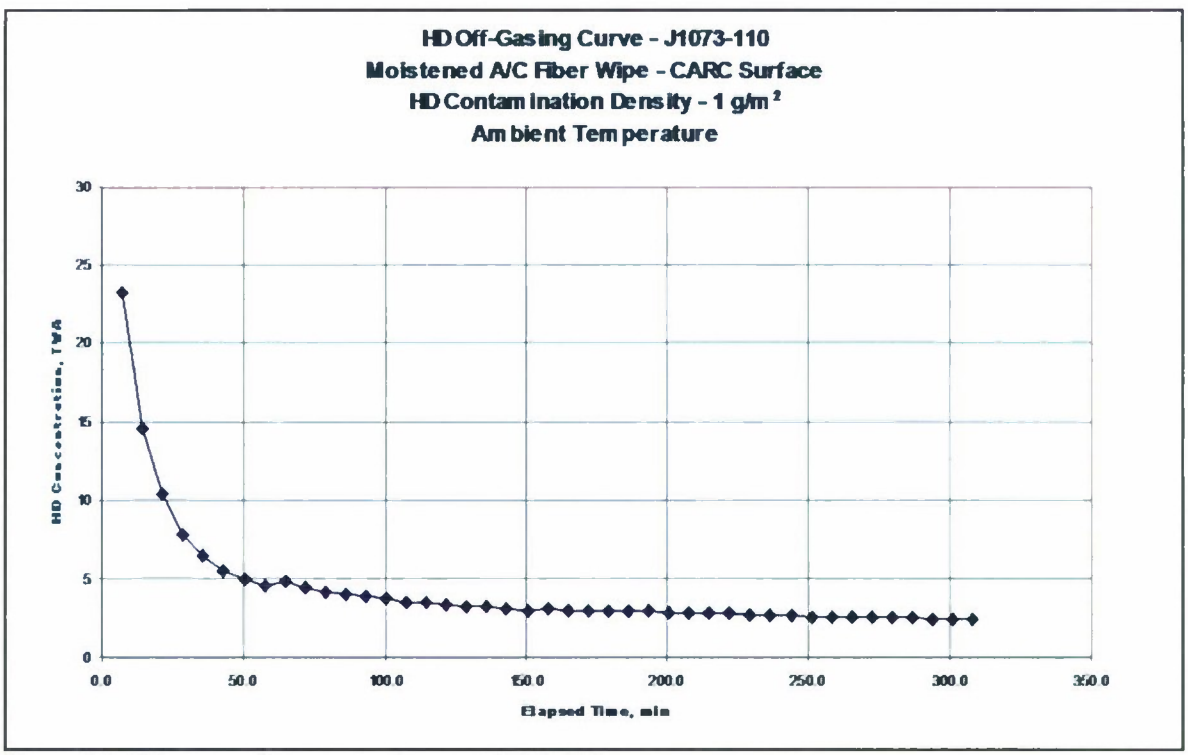


Figure 24. HD vapor off-gas curve from test J1073-110.

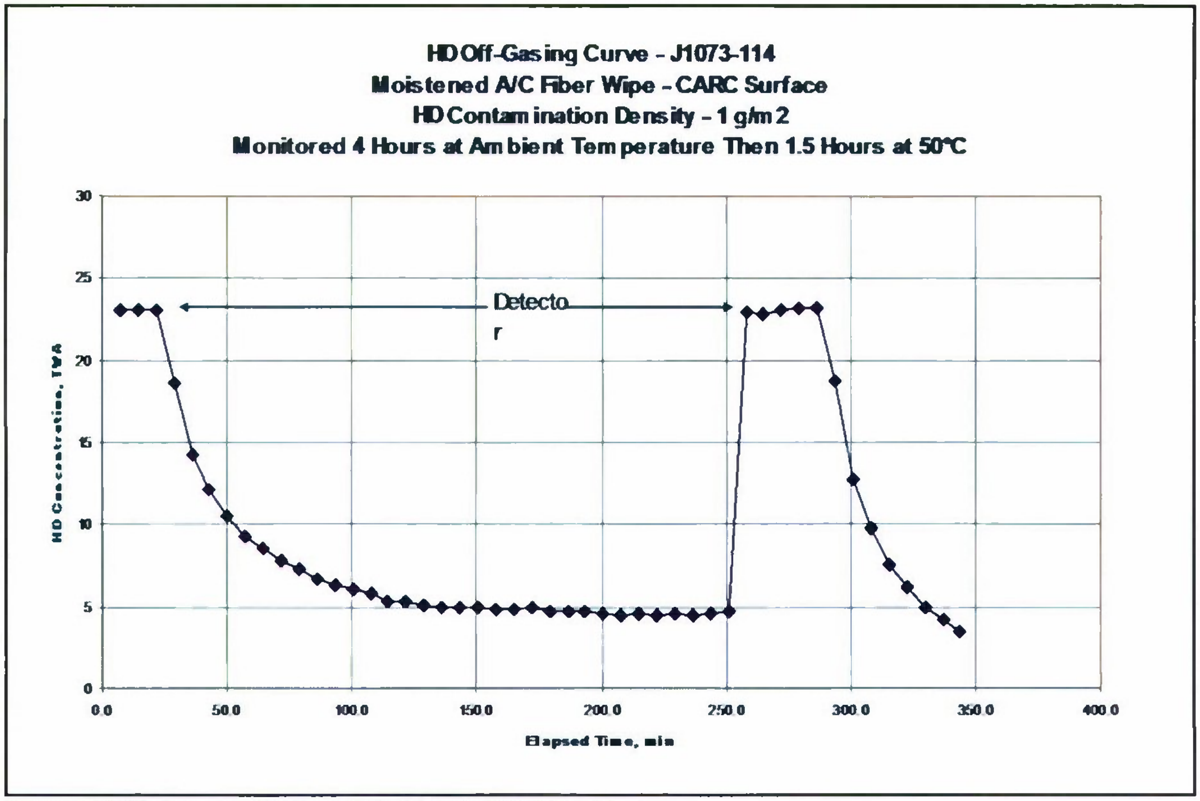


Figure 25. HD vapor off-gas curves from test J1073-114.

With the introduction of absorptive test surfaces into the test matrix, the decision was made at this point to suspend MINICAMS vapor sampling and analysis for the reasons discussed in the following paragraphs.

At the start of this program, vapor off-gas monitoring was the method of choice for the determination of residual agent on wiped surfaces. The goal was to determine the remaining agent vapor hazard present in an enclosed environment, such as the interior of an aircraft, after the decontamination procedure. This information could be used to determine the level of protection that must be used by the crew. Ideally, the sensitive-equipment decontamination procedure would be able to reduce the agent vapor concentration in an enclosed environment to less than 1 TWA.

MINICAMS vapor off-gas monitoring met this goal for HD contamination on non-absorptive aluminum control surfaces. However, as discussed in Section 7.5, because allowable exposure levels for GD and VX are two times lower than those for HD, MINICAMS vapor-off-gas monitoring would not meet the desired near-real-time monitoring goal for GD or VX contamination, even on non-absorptive aluminum control surfaces.

These findings, coupled with incomplete and temperature-dependent agent recoveries from absorptive surfaces by the MINICAMS, led to the decision to discontinue the use of MINICAMS to determine the decontamination efficacies (or wiping efficiencies) of wiping systems and methods.

7.7.2 HD Linear-Wiping Tests on CARC and Alkyd Test Surfaces with Activated Carbon Fabric and Felt Wipes Using HFE-7200 Solvent

The following test procedure was followed for the linear-wiping tests using HD on CARC- and alkyd-painted test coupons:

(1) Mounting the coupons.

- A 2 x 2 in. square x 0.125 in thick CARC- or alkyd-painted test coupon was placed in the cutout slot in the aluminum baseplate of the linear-wiping device.

(2) Attaching the wipe.

- An 8 x 5 in. swatch of wiping material was then cut out and attached to the wiping mandrel. The wiping mandrel was positioned at the far left side of the aluminum baseplate, just to the left of the leftmost aluminum test coupon.

(3) Applying the contaminant.

- The leftmost aluminum test coupon was then uniformly contaminated with 2.6 mg of neat HD, in approximately 1 µL droplets from a microliter syringe, to give an approximate contamination density of 1.0 g/m^2.

(4) Preparing the wiping mandrel.

- After agent contamination, the wiping mandrel was either left in place on the left side of the aluminum baseplate (in the dry tests with no wiping solvent) or was removed from the baseplate, sprayed with HFE-7200 from a manually air-pressurized Misto olive oil sprayer (to wet the wiping material with HFE-7200 without saturation), and then placed back down on the far left side of the aluminum baseplate. The nylon fishing line was then attached to the two eyelets on the opposite sides of the wiping mandrel, routed through the pulley, wrapped around the motor shaft three times, and tensioned by loosening the wing nut on the pulley, moving the pulley away from the motor until the line is taut, and tightening the wing nut.
- In several of the tests, after the deposition of the HD droplets on the surface of the test coupon, HFE-7200 was sprayed directly onto the HD-contaminated aluminum surface from a manually air-pressurized Misto olive oil sprayer rather than onto the wiping material. The sprayed, contaminated surface was then wiped with either a dry wipe or a wipe moistened with HFE-7200. The amount of HFE-7200 sprayed onto the HD-contaminated surface was not quantified, but was sufficient to visually wet the contaminated surface with HFE-7200.

(5) Initiating the wiping sequence.

- After completing the previous steps, a single G240 wiping sequence wiping sequence was initiated from the control computer. The G240 linear-wiping program consisted of six sequential linear wipe passes over the test coupons: (1) a left-to-right pass, (2) a right-to-left return pass, (3) a second left-to-right pass, (4) a second right-to-left return pass, (5) a third left-to-right pass, and (6) a third right-to-left return pass.

- The duration of each pass was 2.0 s, to give a total wipe contact time of 12 s, and the weight of the wiping mandrel was 631g (no added weight).

After the wiping procedure was complete, the amount of residual agent on each test coupon was determined by DAAMS agent vapor sampling and GC-FID analysis.

Using the DAAMS procedure, each of the three aluminum test coupons was removed from the aluminum baseplate and placed in a separate glass sampling jar fitted with air inlet and outlet fittings in the cap of the jar. Room air was pumped into and through the jar and then through a 3 mm OD Tenax TA DAAMS transfer tube at a flow rate of 200 mL/min for the following time periods, replacing the DAAMS tube after each time period:

1. First tube 15 min sample period.

2. Second tube 15 min sample period.

3. Third tube 30 min sample period.

4. Fourth tube 30 min sample period.

5. Fifth tube final 30 min sample period.

Five DAAMS tubes were used to sample sequentially at 200 mL/min for a total of 120 min (a total sample volume of 24 L). Prior to the tests the GC was calibrated. The total amount of HD collected on and desorbed from each DAAMS tube (in ng) was determined directly from GC response of the desorbed DAAMS sample and the HD calibration curve.

The results for each of the tests are given below in Table 33.

As discussed in the previous section, because the post-wiping amount of residual agent remaining on each test coupon was determined by room temperature, agent-vapor, off-gas sampling and analysis, the decontamination efficacy results in the right-most column of the table are expressed as room temperature decontamination efficacies. As discussed in the previous section, there is a significant temperature dependence on the recovery of agent from absorptive surfaces by agent-vapor, off-gas monitoring techniques.

The results of the linear-wiping tests on absorptive surfaces were very similar to the results of the rotary-wiping tests discussed in the previous section. With activated carbon fabric wipes, the HD removal efficiency from CARC-painted surfaces was >99.9%, whether using a dry wipe, an HFE-700-moistened wipe, or a spray-and-wipe technique.

In a limited set of tests with dry and HFE-7200-moistened activated carbon felt wipes, the room temperature HD removal efficiencies from CARC-painted surfaces were somewhat less (approximately 95%) than the corresponding efficiencies with activated carbon fabric (>99.9%).

Table 33. Summary of HD linear wiping tests with CARC- and alkyl-painted surfaces.

Test Conditions:
One iteration of the G240 wiping program – 3 sets of one forward pass followed by one return pass
Wipe Speed – 2 rev/s
Single coupon per test
Low (indoor) HD contamination density – 1.0 g/m^2
DAAMS GC-FID sampling and analysis of wiped test coupon

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Sampling Method	Total Mandrel Weight g	HD Contamination Density g/m^2	Wipe Contact Time s	HD Recovered From Coupon µg	Room Temp. Decon Efficacy %
AC Fabric AW1101	CARC	Linear	Dry wipe	J1190-016	DAAMS/ GC-FID	631	1.0	12	1.60	99.94*
AC Fabric AW1101	CARC	Linear	Wet Wipe (HFE-7200)	J1190-017	DAAMS/ GC-FID	631	1.0	12	1.83	99.93*
AC Fabric AW1101	CARC	Linear	HFE-7200 spray + Dry wipe	J1190-022	DAAMS/ GC-FID	631	1.0	12	3.62	99.86*
AC Fabric AW1101	CARC	Linear	HFE-7200 spray + Wet wipe (HFE-7200)	J1190-023	DAAMS/ GC-FID	631	1.0	12	2.03	99.92*
AC Felt AM1132	CARC	Linear	Dry wipe	J1190-026	DAAMS/ GC-FID	631	1.0	12	128	95.09*
AC Felt AM1132	CARC	Linear	Wet Wipe (HFE-7200)	J1190-027	DAAMS/ GC-FID	631	1.0	12	135	94.81*
AC Fabric AW1103	CARC	Linear	Wet Wipe (HFE-7200)	J1190-030	DAAMS/ GC-FID	631	1.0	12	1.19	99.95*
AC Fabric AW1103	CARC	Linear	Dry wipe	J1190-031	DAAMS/ GC-FID	631	1.0	12	2.89	99.89*
AC Fabric AW1101	Alkyd	Linear	HFE-7200 spray + Wet wipe (HFE-7200)	J1190-034	DAAMS/ GC-FID	631	1.0	12	256	90.15*
AC Fabric AW1101	Alkyd	Linear	HFE-7200 spray + Dry wipe	J1190-035	DAAMS/ GC-FID	631	1.0	12	228	91.24*
AC Fabric AW1101	Alkyd	Linear	Dry wipe	J1190-038	DAAMS/ GC-FID	631	1.0	12	268	89.70*
AC Fabric AW1101	Alkyd	Linear	Wet Wipe (HFE-7200)	J1190-039	DAAMS/ GC-FID	631	1.0	12	262	89.92*

AC Fabric = KoTHmex AW 1101 or AW 1103-activated carbon fabric.
AC Felt = KoTHmex AM1132-activated carbon felt

As with the rotary-wiping tests, because of the agent absorption into the alkyd paint, the room temperature HD decontamination efficacies from alkyd-painted coupons with activated carbon fabric wipes were significantly lower (approximately 90%) than in the corresponding tests with CARC-painted coupons. As in the corresponding tests with CARC-painted coupons, the HD removal efficiencies from alkyd-painted surfaces were the same, whether using a dry wipe, an HFE-7200-moistened wipe, or using a spray-and-wipe technique.

For the same general reasons discussed in Section 7.7.1.2, because of the temperature dependence of vapor off-gas monitoring, after the completion of the preliminary linear-wiping tests, the decision was made to stop using vapor off-gas monitoring to determine post-wipe residual agent remaining on test surfaces. In all subsequent tests, solvent extraction and GC analysis was used.

7.7.3 Tests on Polyethylene and Polycarbonate Test Surfaces with Activated Carbon Fabric and Felt Wipes, Using HFE-7200 and Isopropyl Alcohol Solvents, M295/M100 Sorbent Powder, and MgO Nanoparticle Powder

A brief evaluation of two additional absorptive test surfaces—polycarbonate and high-density-polyethylene (HDPE) plastics—was also conducted. At the same time, the Government requested that the surface-modified activated-alumina reactive sorbent powder (A-200-SiC-1005S), used as the adsorbent resin in the M295 Individual Equipment Decontamination Kit and in the M100 Sorbent Decontamination System, be incorporated into the test matrix to serve as a reference decontaminant. A nanoparticle powder, a potential next-generation reactive sorbent decontaminant, was also incorporated into the text matrix for comparison with the decontamination wipe system.

A magnesium oxide (MgO) nanoparticle powder (NanoActive® Magnesium Oxide Plus) was used in the tests. This material is a high specific-surface-area nanoparticle powder ($\geq$ 600 m^2/g) that has small crystallite size, high porosity, and high chemical reactivity at room and elevated temperatures.

Both reactive sorbent powders were provided for the tests by ECBC through Entropic Systems, Inc.

HD linear-wiping tests were conducted on polycarbonate and high density polyethylene (HDPE) surfaces with dry activated carbon fabric wipes and activated carbon fabric wipes moistened with HFE-7200. HD rotary-wiping tests were conducted on polycarbonate and HDPE surfaces with dry Scotch-Brite® 2021 wipes, with M295/M100 sorbent powder, and with MgO nanoparticle powder. In the tests with sorbent powder and nanoparticle powder, the powdered contaminated surfaces were wiped with Scotch-Brite® 2021 to simulate the material of the car-wash type applicator mitt of the M100 Sorbent Decontamination System.

An HD recovery test was conducted with each of the two types of plastic coupons. In each recovery test, the surface of the test coupon was contaminated with HD droplets at a contamination density of 1.0 g/m^2. After the coupon was contaminated, it was immediately placed into a sample jar with 50 mL of IPA extraction solvent. The jar was allowed to sit with occasional swirling for 2 h, and then the extraction solvent was analyzed for extracted HD by GC-FID.

The procedures for the HD linear-wiping tests were the same as those described previously in this report.

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The procedures for the automated rotary-wiping tests with M295/M100 sorbent powder and with MgO nanoparticle particle powder were similar to the procedures described previously in this report for the automated rotary-wiping tests with dry or solvent-moistened wipe materials. The exception was that decontaminant powder was deposited onto the upper surface of the test panel after contamination of the surface with agent and the powder was removed from the decontaminated surface after the test.

Prior to the start of a test, a predetermined amount of sorbent powder or nanoparticle powder was weighed out on an analytical balance directly into a glass screw top vial.

The test substrate/panel was then mounted in the automated rotary wipe test apparatus, an appropriate wiping material was attached to the rotary wiping mandrel, the PC connection to the rotary-wiping stepper motor was checked and verified, and the upper surface of the test coupon was contaminated with agent.

Immediately after the agent contamination of the exposed surface of the test panel, the decontaminant powder was uniformly deposited over the contaminated surface. This was accomplished by positioning a stainless steel screen holder over the test coupon so that the screen was directly above the coupon. The powder from the glass vial was then poured onto the surface of the screen, being careful to distribute the powder as evenly as possible over the area of the screen directly above the coupon. Then a flux brush, with bristles trimmed to approximately 3/16 in., was used to brush any residual powder through the screen. The screen was then removed and the rotary-wiping procedure was initiated.

After the wiping sequence was completed, and the wiping apparatus was disassembled and removed, a glass pipette connected to a vacuum (with filter trap) was used in conjunction with a trimmed flux brush to remove the residual contaminated powder from the surface of the test coupon.

The results of the tests are summarized in Table 34.

In the linear-wiping tests, with both dry and HFE-7200-moistened activated carbon fabric, the HD removal efficiencies from contaminated high density polyethylene surfaces were very high—greater than 99.7% and >99.9% with dry and HFE-7200-moistened activated carbon fabric, respectively. The corresponding HD removal efficiencies from contaminated polycarbonate surfaces, however, were only 53–54%, with neat HD extensively absorbing into and dissolving the polycarbonate surfaces.

Table 34. Summary of HD rotary and linear wiping tests on polycarbonate and high density polyethylene surfaces with M100 reactive sorbent powder and MgO nanoparticle powder.

Rotary G330 wiping program – 8 clockwise/counterclockwise revolutions at 1.0 rev/s (to simulate thorough wiping)
Linear G180 wiping program – 1 forward pass at 2 s/pass
Single coupon per test
Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis or DAAMS GC-FID

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	HD Contamination Density g/m^2	Wiping Program	HD Recovered From Coupon µg	Decon Efficacy %
AC Fabric	Poly-carbonate	Linear	Dry Wipe	J1190-062	4/16/03	Extraction/ GC-FPD	631	1.0 (Note 1)	1 x G180	1189	54.27
AC Fabric	Poly-carbonate	Linear	HFE-7200	J1190-063	4/16/03	Extraction/ GC-FPD	631	1.0 (Note 1)	1 x G180	1228	52.77
AC Fabric	HDPE	Linear	Dry Wipe	J1190-072	4/18/03	Extraction/ GC-FPD	631	1.0	1 x G180	8	99.71
AC Fabric	HDPE	Linear	HFE-7200	J1190-073	4/18/03	Extraction/ GC-FPD	631	1.0	1 x G180	ND	>99.99
AC Fabric	Poly-carbonate	None	None	J1190-074	4/18/03	Extraction/ GC-FID	631	1.0	None	2307	89% re-covery
AC Fabric	HDPE	None	None	J1190-075	4/18/03	Extraction/ GC-FID	631	1.0	None	2780	107% re-covery
Scotch-Brite	HDPE	Rotary	M100	J1190-100	5/12/03	Extraction/ GC-FPD	350	1.0 (Note 2)	3 x G330	102	96.08
Scotch-Brite	HDPE	Rotary	MgO	J1190-101	5/12/03	Extraction/ GC-FPD	350	1.0 (Note 2)	3 x G330	181	93.03
Scotch-Brite	HDPE	Rotary	Dry Wipe	J1190-102	5/12/03	Extraction/ GC-FPD	350	1.0	3 x G330	26	99.00
Scotch-Brite	Poly-carbonate	Rotary	Dry Wipe	J1190-103	5/12/03	Extraction/ GC-FPD	350	1.0 (note 1)	3 x G330	561	78.42
Scotch-Brite	Poly-carbonate	Rotary	M100	J1190-104	5/12/03	Extraction/ GC-FPD	350	1.0 (Note 1)	3 x G330	1081	58.44
Scotch-Brite	Poly-carbonate	Rotary	MgO	J1190-105	5/12/03	Extraction/ GC-FPD	350	1.0 (Note 1)	3 x G330	824	68.30

Note 1: HD appears to dissolve into and pit surface of polycarbonate
Note 2: MgO and M100 powders appear to abrade surface of HDPE

AC Fabric = KoTHmex AW 1101-activated carbon fabric.
Scotch-Brite = 3M Scotch-Brite 2021
HDPE = High Density Polyethylene
M100 = Reactive Sorbent Powder
MgO = Nanoparticle Powder
ND = No Residual Agent Detected. The estimated limit of detection was ? µg.

In the rotary-wiping tests with dry Scotch-Brite® wipes using M295/M100 sorbent powder and MgO nanoparticle powder, the results were similar with 93–99% HD removal efficiency from HD-contaminated HDPE surfaces, but only 58–78% HD removal efficiency from HD-contaminated polycarbonate surfaces.

In the HD recovery tests, 89% of the HD deposited on the polycarbonate surface was recovered by IPA solvent extraction and GC-FPD analysis, and >100% of the HD deposited on the HDPE surface was recovered.

In the tests with both the polycarbonate test coupons and the HDPE test coupons, the HD decontamination efficacies of the dry Scotch-Brite® wipes were somewhat greater than the corresponding efficiencies with the M295/M100 sorbent powder or the MgO nanoparticle powder. The decontamination efficacies with the M295/M100 sorbent powder were greater than the corresponding efficiencies with the MgO nanoparticle powder.

Visual examination of the test surfaces after the completion of the tests indicated that both the M295/M100 sorbent powder and the MgO nanoparticle powder appeared to scratch the surfaces of the HDPE coupons.

7.7.4 Abrasion Tests with M295/M100 Sorbent Powder and MgO Nanoparticle Powder

On the basis of the visual observation of apparent surface scratching of the HDPE surfaces by M295/M100 sorbent powder and MgO nanoparticle powder in the previous set of tests discussed in Section 7.7.3, a brief set of cursory abrasion tests was conducted with the powders. Polycarbonate test coupons and small first-surface mirrors were used in the abrasion tests to determine if the powders would scratch the surfaces of materials that could be used in the fabrication of sensitive electronic and optical devices.

The tests were conducted with the automated rotary test apparatus. A test coupon was mounted in the test apparatus, the surface of the coupon was manually coated with sorbent powder or nanoparticle powder, and the powder-coated surface was wiped with three iterations of the G330 rotary-wiping program (for a total wipe contact time of 48 s). In about half of the tests the surfaces were wiped with Scotch-Brite® 2021 to simulate the material of the car-wash-type applicator mitt of the M100 Sorbent Decontamination System. In the remainder of the tests the surfaces were wiped with KoTHmex AW 1101-activated carbon fabric. Control tests were conducted on both surfaces with each of the two wipe materials and no sorbent powder.

After each wipe test was completed, and the powder was vacuumed from the surface of the test coupon (if applicable), the coupon was removed from the rotary test apparatus and visually examined by eye and under a low-power stereo microscope for any signs of surface scratches.

The results of the tests are summarized in Table 35. No surfaces scratches were observed in any of the tests with polycarbonate or mirrored surfaces. However, in one test conducted with activated carbon fabric and no powder, on an HDPE surface, the surface of the HDPE did seem to be dulled by the dry fabric wiping, although no surface scratches were observed. Because of the Government's request to focus on aluminum, CARC and alkyl-painted surfaces, and nylon webbing, and eliminate the plastic surfaces from the remainder of the test program, this observation of HDPE surface dulling was not examined any further.

Table 35. Summary of HD abrasion tests with polycarbonate, polyethylene, and mirrored surfaces with M100 reactive sorbent powder and MgO nanoparticle powder.

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	HD Contamination Density g/m^2	Wiping Program	Wipe Contact Time s	Observations
Scotch-Brite	Poly-carbonate	Rotary	M100	J1190-096	5/07/03	None	350	No Agent	3 x G330	48	No surface scratches
Scotch-Brite	Poly-carbonate	Rotary	MgO	J1190-097	5/07/03	None	350	No Agent	3 x G330	48	No surface scratches
Scotch-Brite	Poly-carbonate	Rotary	Dry Wipe	J1190-098	5/08/03	None	350	No Agent	3 x G330	48	No surface scratches
Scotch-Brite	Mirror	Rotary	Dry Wipe	J1190-108	5/14/03	None	350	No Agent	3 x G330	48	No surface scratches
AC Fabric	Mirror	Rotary	M100	J1190-109	5/14/03	None	350	No Agent	3 x G330	48	No surface scratches
Scotch-Brite	Mirror	Rotary	MgO	J1190-110	5/14/03	None	350	No Agent	3 x G330	48	No surface scratches
AC Fabric	Poly-carbonate	Rotary	Dry Wipe	J1190-111	5/14/03	None	350	No Agent	3 x G330	48	No surface scratches
AC Fabric	HDPE	Rotary	Dry Wipe	J1190-112	5/14/03	None	350	No Agent	3 x G330	48	Surface appeared dulled by wiping
AC Fabric	Mirror	Rotary	Dry Wipe	J1190-113	5/14/03	None	350	No Agent	3 x G330	48	No surface scratches

7.7.5 Tests on Aluminum, CARC, and Alkyd Test Surfaces with Activated Carbon Fabric and Felt Wipes Using HFE-7200 and Isopropyl Alcohol Solvents, M295/M100 Sorbent Powder, and MgO Nanoparticle Powder

A series of automated HD rotary-wiping tests were conducted on CARC- and alkyd-painted surfaces, and (for comparison) aluminum control surfaces, with activated carbon fabric and felt wipes, HFE-7200 and isopropyl alcohol solvents, using M295/M100 sorbent powder as a reference control and MgO nanoparticle powder for comparison.

The HD contamination density for all of the tests was the indoor contamination density of 1.0 g/m^2. All tests were conducted with three iterations of the G330 rotary-wiping program to give a wipe contact time of 48 s in each test. The residual agent on each test coupon after the completion of the wipe/decontamination procedure was determined by solvent extraction (in IPA) and GC-FPD analysis.

The automated rotary-wiping tests were conducted according to the procedures described in Sections 6.2 and 6.3. These procedures were the same as those described in Sections 7.7.1 and 7.7.3, except for the elimination of the stainless steel screen for powder deposition in the tests with M295/M100 sorbent powder and MgO nanoparticle powder. In this set of tests and in all subsequent tests with M295/M100 sorbent powder and MgO nanoparticle powder, after the agent contamination of the exposed surface of the test coupon, a pre-weighed amount of decontaminant powder was uniformly deposited directly from a vial of powder over the contaminated surface of the test panel. A single researcher deposited the powder on the contaminated test surface in a careful, uniform, and reproducible manner in all of the tests.

The results of the tests are summarized in Table 36.

Regardless of the wiping or decontamination method used in the tests, as observed in the previous tests discussed in this report, the HD decontamination efficacy was greatest from the non-absorptive aluminum test coupons (>99% in all of the tests), slightly less from the CARC-painted test panels (an overall average of approximately 98%), and significantly less from the alkyd-painted test panels (an overall average of approximately 51%).

Comparing the various wipe and decontamination systems in this limited set of tests, within the variability and spread of the test results there was relatively little difference in the HD decontamination efficacies between the dry wipes (whether Scotch-Brite® or activated carbon fabric), solvent-moistened wipes (HFE-7200 or IPA solvents), M295/M100 powder, or MgO nanoparticle powder.

A more extensive set of comparison tests between the various methods, agents, and test surfaces was conducted to conclude this program. These tests are discussed in the next section of this report (Section 7.8).

In the tests with sorbent powder and nanoparticle powder, three different materials were compared as sorbent applicators for the M295/M100 powder and the MgO nanoparticle powder—Scotch-Brite® 2021, a commercial chamois cloth, and KoTHmex AW 1101-activated carbon fabric. Within the variability of the test results there appeared to be no significant difference between the three materials as sorbent applicators.

Table 36. Summary of HD rotary-wiping tests with CARC- and alkyd-painted panels and with M100 reactive sorbent powder, MgO nanoparticle powder, HFE7200, and IPA.

Rotary G330 wiping program – 8 clockwise/counterclockwise revolutions at 1.0 rev/s (to simulate thorough wiping)
Single coupon per test, Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight G	HD Contamination Density g/m^2	Wipe Contact Time s	HD Recovered From Coupon µg	Decon Efficacy %
Scotch-Brite	Aluminum	Rotary	M100	J1190-114	5/20/03	Extraction/ GC-FPD	350	1.0	48	ND	>99.99
AC Fabric	Aluminum	Rotary	M100	J1190-116	5/20/03	Extraction/ GC-FPD	350	1.0	48	18	98.77
Scotch-Brite	Aluminum	Rotary	MgO	J1190-117	5/20/03	Extraction/ GC-FPD	350	1.0	48	ND	>99.99
AC Fabric	Aluminum	Rotary	MgO	J1190-115	5/20/03	Extraction/ GC-FPD	350	1.0	48	ND	>99.99
Scotch-Brite	Aluminum	Rotary	None	J1190-118	5/20/03	Extraction/ GC-FPD	350	1.0	48	13	99.09
AC Fabric	CARC	Rotary	None	J1190-129	6/18/03	Extraction/ GC-FPD	350	1.0	48	20	99.2
Scotch-Brite	CARC	Rotary	None	J1190-128	6/18/03	Extraction/ GC-FPD	350	1.0	48	26	99.0
AC Fabric	CARC	Rotary	HFE-7200	J1190-130	6/18/03	Extraction/ GC-FPD	350	1.0	48	31	98.8
AC Fabric	CARC	Rotary	IPA	J1190-131	6/18/03	Extraction/ GC-FPD	350	1.0	48	50	98.1
Chamois	CARC	Rotary	M100	J1190-132	6/18/03	Extraction/ GC-FPD	350	1.0	48	66	97.5
AC Fabric	CARC	Rotary	M100	J1190-126	6/18/03	Extraction/ GC-FPD	350	1.0	48	78	97.0
Scotch-Brite	CARC	Rotary	M100	J1190-124	6/18/03	Extraction/ GC-FPD	350	1.0	48	35	98.6
AC Fabric	CARC	Rotary	MgO	J1190-125	6/18/03	Extraction/ GC-FPD	350	1.0	48	59	97.7
Scotch-Brite	CARC	Rotary	MgO	J1190-127	6/18/03	Extraction/ GC-FPD	350	1.0	48	105	96.0
AC Fabric	Alkyd	Rotary	None	J1190-138	6/18/03	Extraction/ GC-FPD	350	1.0	48	879	66.2
Scotch-Brite	Alkyd	Rotary	None	J1190-137	6/18/03	Extraction/ GC-FPD	350	1.0	48	1533	41.1
AC Fabric	Alkyd	Rotary	HFE-7200	J1190-139	6/18/03	Extraction/ GC-FPD	350	1.0	48	1033	60.3
AC Fabric	Alkyd	Rotary	IPA	J1190-140	6/18/03	Extraction/ GC-FPD	350	1.0	48	503	80.7
Chamois	Alkyd	Rotary	M100	J1190-141	6/18/03	Extraction/ GC-FPD	350	1.0	48	1318	49.3
AC Fabric	Alkyd	Rotary	M100	J1190-135	6/18/03	Extraction/ GC-FPD	350	1.0	48	1640	36.9
Scotch-Brite	Alkyd	Rotary	M100	J1190-133	6/18/03	Extraction/ GC-FPD	350	1.0	48	1720	33.9
AC Fabric	Alkyd	Rotary	MgO	J1190-134	6/18/03	Extraction/ GC-FPD	350	1.0	48	1807	30.5
Scotch-Brite	Alkyd	Rotary	MgO	J1190-136	6/18/03	Extraction/ GC-FPD	350	1.0	48	2426	6.68 (?)

AC Fabric = KoTHmex AW 1101-activated carbon fabric.
Scotch-Brite = 3M Scotch-Brite 2021
HDPE = High Density Polyethylene
M100 = 25 ± 1 Reactive Sorbent Powder (SDS)
MgO = 25 ± 1 Nanoparticle Powder
ND = No Residual Agent Detected.
Note: There was a visible discoloration left on the surface of the Alkyd panels after the wiping process. This was observed in all the Alkyd tests above. There was no such discoloration on the CARC panels.

7.8 Comparative Rotary-Wiping Tests with Activated Carbon Fabric

The final set of agent tests was a series of comparative rotary-wiping tests. The tests were designed to compare the rotary-wiping decontamination efficacy/surface-removal efficiency of the activated carbon fabric wipe. The activated carbon fabric wipe was judged to be the most effective wipe material for the removal of HD, TGD, and VX from a range of test surfaces, with a variety of candidate and control solvents or decontaminants, on the basis of the previous agent testing, conducted under identical rotary-wiping test conditions.

The variables in the comparative rotary-wiping tests were:

- Agent: HD, TGD, and VX
- Test Surface: Aluminum, CARC-painted stainless steel panel, alkyd-painted stainless steel panel, and nylon webbing
- Solvent or Decontaminant: None (dry wipe), HFE-7200, isopropanol, M295/M100 sorbent powder, and MgO nanoparticle particle powder

In all of the HD tests, except those with nylon webbing, the most effective non-adsorptive wipe material (Scotch-Brite™ 2021) was also included in the test set.

Nylon webbing (MIL-C-7219F), commonly used in the interior of military transport aircraft, was provided for incorporation into the comparative-test set. The nylon webbing was a potentially agent-absorptive material that would complete the range of test surfaces from non-absorptive (aluminum), to slightly absorptive (CARC-painted panels), to moderately absorptive (alkyd-painted panels), to very absorptive (nylon webbing). As the comparative wipe test results subsequently indicated, however, the nylon webbing showed little agent absorption.

All of the tests were conducted under the same set of rotary-wiping test parameters and conditions:

- Ambient temperature and relative humidity
- One iteration of the G300 rotary-wiping program (8 s wipe contact time)
- 350 g total rotary-wiping mandrel weight
- 1.0 g/m^2 agent contamination density
- Extraction/GC-FPD analysis of post-wipe residual agent on test surface

An 8 s rotary-wiping program for this set of comparative-wipe tests was selected over the 48 s thorough wipe contact time used in most of the previous rotary-wiping tests. The shorter wipe time more closely simulated manual wiping and provided a less than thorough wiping, which would potentially differentiate between the various wipe test variables.

Time and budget constraints prevented the performance of an identical set of comparative linear-wiping tests.

7.8.1 Test Procedures

7.8.1.1 Automated Rotary-Wiping Procedures for Dry and Solvent-Moistened Wipes

The automated rotary-wiping device tests were conducted at room temperature and ambient relative humidity using the test procedures described in Sections 6.2 and 6.3. Each test was conducted using the 350 g aluminum rotary-wiping mandrel with no added weight. In each test a single wipe sequence was employed—one iteration of the G300 rotary-wiping program command, consisting of four successive clockwise/counterclockwise rotations at a wiping speed of 1.0 rev/s, giving a total wipe contact time of 8 s. This 8 s wiping sequence was selected in the comparative tests to represent a more realistic wiping procedure (in terms of wipe contact time) than four iterations of the G330 "thorough" wipe program (48 s wipe contact time).

In a given test, the surface of a 1.5 x 1.5 in. square aluminum test coupon or a 2 x 2 x 0.125 in. CARC- or alkyd-painted stainless steel panel was mounted in the rotary-wiping device. In the tests with the nylon webbing, a 2 in. square swatch of the webbing was mounted on an aluminum test coupon with the edges of the nylon swatch extending beyond each of the four edges of the aluminum test coupon. The extended edges of the nylon webbing were folded down around the edges of the aluminum test coupon, and the aluminum coupon was pushed up through the underside of the template opening of the baseplate until the surface of the nylon webbing was flush with the upper (wiping) surface of the aluminum baseplate.

Each test surface was then uniformly contaminated with either 1.45 mg of agent (in the tests with aluminum and nylon webbing) or 2.6 mg (in the tests with painted surfaces) to give an agent contamination density of 1.0 g/m^2 in each of the tests. Neat agent was deposited as approximately 1 µL droplets from a 10 µL syringe to generate the indoor (low) threat agent contamination density. Thickened GD was deposited as approximately 2 µL droplets from a micropipettor. The agent was generally deposited over the center 1 in. square of each test coupon.

The wiping mandrel with a preattached dry wipe or a wipe moistened with HFE-7200 or IPA was then placed on top of the agent-contaminated surface so that the turning pin on the shaft of the stepper motor was positioned in the slotted shaft of the wiping mandrel. The single iteration of the G300 wiping command was then input to the wiping device from the keyboard of the control PC.

After the wiping procedure was complete, the residual agent on the test surface after wiping was determined by GC-FPD analysis of the solvent extract, as described in Section 6.5.

Using the extraction procedure, after the completion of the wipe portion of the test, the test coupon was removed from the aluminum baseplate and placed in a separate jar containing 25 mL of isopropyl alcohol (in the tests with aluminum coupons or nylon webbing) or 50 mL (in the tests with painted coupons). The jar was sealed, and the test coupon was allowed to soak in the IPA for 120 min with intermittent swirling to extract any residual agent on the test coupon into the IPA extraction solvent. After the 120 min extraction period, the IPA extract was analyzed for residual HD by GC-FPD.

7.8.1.2 Automated Rotary-Wiping Procedures for Sorbent Powder Decontaminant

The procedures for the automated rotary-wiping tests with M295/M100 sorbent powder and with MgO nanoparticle particle powder were identical to the procedures used in the automated rotary-wiping tests with dry or solvent-moistened wipe materials described in Section 7.8.1.1, with one exception. The deposition of the decontaminant powder onto the upper surface of the test panel after the contamination with agent, and the removal of the powder from the decontaminated surface after the test was different.

Prior to the start of a test, a predetermined amount of sorbent powder or nanoparticle powder was weighed out on an analytical balance directly into a glass screw top vial.

The test substrate/panel was then mounted in the automated rotary wipe test apparatus, an appropriate wiping material was attached to the rotary-wiping mandrel, the PC connection to the rotary-wiping stepper motor was checked and verified, and the upper surface of the test coupon was contaminated with agent.

Immediately contaminating the test panel surface, the decontaminant powder was manually and uniformly deposited over the contaminated surface by gently shaking the powder out of the screw top vial onto the surface.

After the wiping sequence was completed, and the wiping apparatus was disassembled and removed, a glass pipette connected to a vacuum (with filter trap) was used in conjunction with a trimmed flux brush to remove the residual contaminated powder from the surface of the test coupon.

In the tests with sorbent powder and nanoparticle powder discussed in Section 7.7.5, three different materials were compared as sorbent applicators for the M295/M100 powder and the MgO nanoparticle powder—Scotch-Brite® 2021, a commercial chamois cloth, and KoTHmex AW 1101-activated carbon fabric. Within the variability of the test results there appeared to be no significant difference in the three materials as sorbent applicators.

In the HD comparative-wipe tests with aluminum test coupons, CARC-painted panels, and alkyd-painted panels, both activated carbon fabric and Scotch-Brite® 2021 were used as applicators/wipes with the M295/M100 sorbent powder and the MgO nanoparticle powder. Again, within the variability of the test results, there appeared to be no significant difference in the two materials as sorbent applicators, and activated carbon fabric was used as the powder applicator in the remaining rotary comparative-wipe tests.

7.8.2 Results

The detailed results of the comparative rotary-wiping tests are given in Table 38 through Table 51. A key to the test results is given in Table 37.

The results of the comparative rotary-wiping tests are summarized in Table 52 and are presented graphically in bar-chart format in Figure 26 through Figure 29. Each bar chart shows a side-by-side comparison of the measured decontamination efficacy of each wipe/solvent/decontaminant combination for a given agent, on each of the test surfaces that were contaminated and then wiped or decontaminated.

- Figure 26 displays the results of the HD rotary-wiping tests with activated carbon fabric.
- Figure 27 displays the results of the VX rotary-wiping tests with activated carbon fabric.
- Figure 28 displays the results of the TGD rotary-wiping tests with activated carbon fabric.
- Figure 29 displays the results of the HD rotary-wiping tests with Scotch-Brite™.

Table 37. Key to the detailed test results in Tables 37 through 51.

Table Number	Agent	Test Surface	Wiping Material	Solvent or Decon
34	HD	Aluminum	AC Fabric	None, HFE-7200, IPA, M100, MgO
			Scotch-Brite	None, HFE-7200, IPA, M100, MgO
35	HD	CARC	AC Fabric	None, HFE-7200, IPA, M100, MgO
36	HD	Alkyd	AC Fabric	None, HFE-7200, IPA, M100, MgO
37	HD	CARC	Scotch-Brite	None, HFE-7200, IPA, M100, MgO
38	HD	Alkyd	Scotch-Brite	None, HFE-7200, IPA, M100, MgO
39	HD	Nylon	AC Fabric	None, HFE-7200, IPA, M100, MgO
40	VX	Aluminum	AC Fabric	None, HFE-7200, IPA, M100, MgO
41	VX	CARC	AC Fabric	None, HFE-7200, IPA, M100, MgO
42	VX	Alkyd	AC Fabric	None, HFE-7200, IPA, M100, MgO
43	VX	Nylon	AC Fabric	None, HFE-7200, IPA, M100, MgO
44	TGD	Aluminum	AC Fabric	None, HFE-7200, IPA, M100, MgO
45	TGD	CARC	AC Fabric	None, HFE-7200, IPA, M100, MgO
46	TGD	Alkyd	AC Fabric	None, HFE-7200, IPA, M100, MgO
47	TGD	Nylon	AC Fabric	None, HFE-7200, IPA, M100, MgO

Table 38. Results of HD rotary-wiping tests on aluminum coupons with no powder, M100 reactive sorbent powder, MgO nanoparticle powder, HFE-7200, and IPA.

Activated carbon fabric and Scotch-Brite™
Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s
Single coupon per test
Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	HD Contamination Density g/m^2	Wiping Program	HD Recovered From Coupon µg	Decon Efficacy %
AC Fabric	Aluminum	Rotary	None	K023-006	6/24/03	Extraction/ GC-FPD	350	1.0	1 x G300	2	99.9
Scotch-Brite	Aluminum	Rotary	None	K023-011	6/24/03	Extraction/ GC-FPD	350	1.0	1 x G300	103	92.9
AC Fabric	Aluminum	Rotary	HFE-7200	K023-009	6/24/03	Extraction/ GC-FPD	350	1.0	1 x G300	<1	>99.9
Scotch-Brite	Aluminum	Rotary	HFE-7200	K023-014	6/24/03	Extraction/ GC-FPD	350	1.0	1 x G300	1	99.9
AC Fabric	Aluminum	Rotary	IPA	K023-010	6/24/03	Extraction/ GC-FPD	350	1.0	1 x G300	1	99.9
Scotch-Brite	Aluminum	Rotary	IPA	K023-015	6/24/03	Extraction/ GC-FPD	350	1.0	1 x G300	<1	>99.9
AC Fabric	Aluminum	Rotary	M100	K023-007	6/24/03	Extraction/ GC-FPD	350	1.0	1 x G300	11	99.3
Scotch-Brite	Aluminum	Rotary	M100	K023-012	6/24/03	Extraction/ GC-FPD	350	1.0	1 x G300	2	99.8
AC Fabric	Aluminum	Rotary	MgO	K023-008	6/24/03	Extraction/ GC-FPD	350	1.0	1 x G300	1	99.9
Scotch-Brite	Aluminum	Rotary	MgO	K023-013	6/24/03	Extraction/ GC-FPD	350	1.0	1 x G300	1	99.9

AC Fabric = KoTHmex AW 1101 activated carbon fabric.
Scotch-Brite = 3M Scotch-Brite 2021
M100 = 25 ± 1 mg M100 Powder
MgO = 25 ± 1 MgO Nanoparticle Powder
ND = No Residual Agent Detected

Table 39. Results of HD rotary-wiping tests on CARC-painted stainless steel coupons with M100 reactive sorbent powder, MgO nanoparticle powder, HFE-7200, and IPA.

Activated carbon fabric
Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s
Single coupon per test, test done in duplicate
Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	HD Contamination Density g/m^2	Wiping Program	HD Recovered From Coupon µg	Decon Efficacy % (Note 1)
AC Fabric	CARC	Rotary	None	K023-022A	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	25	99.0
AC Fabric	CARC	Rotary	None	K023-022B	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	10	99.6
AC Fabric	CARC	Rotary	HFE-7200	K023-023A	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	48	98.1
AC Fabric	CARC	Rotary	HFE-7200	K023-023B	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	17	99.3
AC Fabric	CARC	Rotary	IPA	K023-024A	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	45	98.3
AC Fabric	CARC	Rotary	IPA	K023-024B	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	53	98.0
AC Fabric	CARC	Rotary	M100	K023-025A	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	69	97.4
AC Fabric	CARC	Rotary	M100	K023-025B	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	39	98.5
AC Fabric	CARC	Rotary	MgO	K023-026A	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	29	98.9
AC Fabric	CARC	Rotary	MgO	K023-026B	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	23	99.1

AC Fabric = KoTHmex AW 1101 activated carbon fabric.
M100 = 25 ± 1 mg M100 Powder
MgO = 25 ±11 MgO Nanoparticle Powder

Note 1: There was a visible discoloration left on the surface of the Alkyd panels after the wiping process. This was observed in all the Alkyd tests above. There was no such discoloration on the CARC panels.

Table 40. Results of HD rotary-wiping tests on alkyd-painted stainless steel coupons with M100 reactive sorbent powder, MgO nanoparticle powder, HFE-7200, and IPA.

Activated carbon fabric
Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s
Single coupon per test, test done in duplicate
Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	HD Contamination Density g/m^2	Wiping Program	HD Recovered From Coupon µg	Decon Efficacy % (Note 1)
AC Fabric	Alkyd	Rotary	None	K023-027A	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	1345	48.3
AC Fabric	Alkyd	Rotary	None	K023-027B	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	982	62.3
AC Fabric	Alkyd	Rotary	HFE-7200	K023-028A	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	656	74.8
AC Fabric	Alkyd	Rotary	HFE-7200	K023-028B	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	1130	56.4
AC Fabric	Alkyd	Rotary	IPA	K023-029A	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	569	78.1
AC Fabric	Alkyd	Rotary	IPA	K023-029B	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	578	77.8
AC Fabric	Alkyd	Rotary	M100	K023-030A	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	1097	57.8
AC Fabric	Alkyd	Rotary	M100	K023-030B	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	1198	53.9
AC Fabric	Alkyd	Rotary	MgO	K023-031A	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	1375	47.1
AC Fabric	Alkyd	Rotary	MgO	K023-031B	7/02/03	Extraction/ GC-FPD	350	1.0	1 x G300	1719	33.9

AC Fabric = KoTHmex AW 1101-activated carbon fabric.
M100 = 25 ± 1 mg M100 Powder
MgO = 25 ±11 MgO Nanoparticle Powder
Note 1: There was a visible discoloration left on the surface of the Alkyd panels after the wiping process. This was observed in all the Alkyd tests above. There was no such discoloration on the CARC panels.

Table 41. Results of HD rotary-wiping tests on CARC-painted stainless steel coupons with M100 reactive sorbent powder, MgO nanoparticle powder, HFE-7200, and IPA.

3M Scotch-Brite™ 2021 White
Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s
Single coupon per test, test done in duplicate
Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	HD Contamination Density g/m^2	Wiping Program	HD Recovered From Coupon µg	Decon Efficacy %
Scotch -Brite	CAR C	Rotary	None	K023-032A	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	164	93.7
Scotch -Brite	CAR C	Rotary	None	K023-032B	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	178	93.2
Scotch -Brite	CAR C	Rotary	HFE-7200	K023-033A	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	381	85.4
Scotch -Brite	CAR C	Rotary	HFE-7200	K023-033B	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	69	97.3
Scotch -Brite	CAR C	Rotary	IPA	K023-034A	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	67	97.4
Scotch -Brite	CAR C	Rotary	IPA	K023-034B	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	90	97.3
Scotch -Brite	CAR C	Rotary	M100	K023-035A	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	18	99.3
Scotch -Brite	CAR C	Rotary	M100	K023-035B	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	15	99.4
Scotch -Brite	CAR C	Rotary	MgO	K023-036A	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	109	95.8
Scotch -Brite	CAR C	Rotary	MgO	K023-036B	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	30	98.8

Scotch-Brite = 3M Scotch-Brite 2021
M100 = 25 ± 1 mg M100 Powder
MgO = 25 ± 1 mg MgO Nanoparticle Powder

Table 42. Results of HD rotary-wiping tests on alkyd-painted stainless steel coupons with M100 reactive sorbent powder, MgO nanoparticle powder, HFE-7200, and IPA.

3M Scotch-Brite™ 2021 White
Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s
Single coupon per test, test done in duplicate
Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	HD Contamination Density g/m^2	Wiping Program	HD Recovered From Coupon µg	Decon Efficacy %
Scotch-Brite	Alkyd	Rotary	None	K023-037A	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	2447	5.9
Scotch-Brite	Alkyd	Rotary	None	K023-037B	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	2380	8.5
Scotch-Brite	Alkyd	Rotary	HFE-7200	K023-038A	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	2217	14.7
Scotch-Brite	Alkyd	Rotary	HFE-7200	K023-038B	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	1996	23.2
Scotch-Brite	Alkyd	Rotary	IPA	K023-039A	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	898	65.5
Scotch-Brite	Alkyd	Rotary	IPA	K023-039B	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	1377	47.1
Scotch-Brite	Alkyd	Rotary	M100	K023-040A	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	1222	53.0
Scotch-Brite	Alkyd	Rotary	M100	K023-040B	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	1446	44.4
Scotch-Brite	Alkyd	Rotary	MgO	K023-041A	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	2123	18.3
Scotch-Brite	Alkyd	Rotary	MgO	K023-041B	7/09/03	Extraction/ GC-FPD	350	1.0	1 x G300	2384	8.3

Scotch-Brite = 3M Scotch-Brite 2021.
M100 = 25 ± 1 mg M100 Powder
MgO = 25 ± 1 mg MgO Nanoparticle Powder

Table 43. Results of HD rotary-wiping tests on nylon webbing samples with M100 reactive sorbent powder, MgO nanoparticle powder, HFE-7200, and IPA.

Activated carbon fabric
Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s
Single coupon per test, test done in duplicate
Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	HD Contamination Density g/m^2	Wiping Program	HD Recovered From Coupon µg	Decon Efficacy % (notes 1, 2)
AC Fabric	NYLON WEB	Rotary	None	K023-056A	8/04/03	Extraction/ GC-FPD	350	1.0	1 x G300	14	99.1
AC Fabric	NYLON WEB	Rotary	None	K023-056B	8/04/03	Extraction/ GC-FPD	350	1.0	1 x G300	13	99.1
AC Fabric	NYLON WEB	Rotary	HFE-7200	K023-057A	8/04/03	Extraction/ GC-FPD	350	1.0	1 x G300	58	96.0
AC Fabric	NYLON WEB	Rotary	HFE-7200	K023-057B	8/04/03	Extraction/ GC-FPD	350	1.0	1 x G300	65	95.5
AC Fabric	NYLON WEB	Rotary	IPA	K023-058A	8/04/03	Extraction/ GC-FPD	350	1.0	1 x G300	235	83.8
AC Fabric	NYLON WEB	Rotary	IPA	K023-058B	8/04/03	Extraction/ GC-FPD	350	1.0	1 x G300	82	94.3
AC Fabric	NYLON WEB	Rotary	M100	K023-059A	8/04/03	Extraction/ GC-FPD	350	1.0	1 x G300	69	95.3
AC Fabric	NYLON WEB	Rotary	M100	K023-059B	8/04/03	Extraction/ GC-FPD	350	1.0	1 x G300	120	91.7
AC Fabric	NYLON WEB	Rotary	MgO	K023-060A	8/04/03	Extraction/ GC-FPD	350	1.0	1 x G300	34	97.7
AC Fabric	NYLON WEB	Rotary	MgO	K023-060B	8/04/03	Extraction/ GC-FPD	350	1.0	1 x G300	73	94.9

AC Fabric = KoTHmex AW 1101-activated carbon fabric.
M100 = 25 ± 1 mg M100Powder
MgO = 25 ± 1 mg MgO Nanoparticle Powder
Note 1: The agent droplets tended to bead up when placed onto the surface of the fabric, as opposed to spreading when placed onto the metal and plastic coupons.
Note 2: It was difficult to remove the powder decontaminants from the surface of the fabric. Some of the observed recovery is probably attributable to agent carried to the extraction solvent in the powder.

Table 44. Results of VX rotary-wiping tests on aluminum coupons with M100 reactive sorbent powder, MgO nanoparticle powder, HFE-7200, and IPA.

Using Activated Charcoal Fabric only, and Fabric
Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s
Single coupon per test, test done in duplicate
Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	VX Contamination Density g/m^2	Wiping Program	VX Recovered From Coupon µg	Decon Efficacy %
AC Fabric	ALUMINUM	Rotary	None	K023-062A	8/19/03	Extraction/ GC-FPD	350	1.0	1 x G300	50	96.6
AC Fabric	ALUMINUM	Rotary	None	K023-062B	8/19/03	Extraction/ GC-FPD	350	1.0	1 x G300	67	95.4
AC Fabric Double Layer	ALUMINUM	Rotary	None	K023-086A	8/19/03	Extraction/ GC-FPD	350	1.0	1 x G300	137	90.6
AC Fabric Double Layer	ALUMINUM	Rotary	None	K023-086B	8/19/03	Extraction/ GC-FPD	350	1.0	1 x G300	50	96.6
AC Fabric	ALUMINUM	Rotary	HFE-7200	K023-063A	8/19/03	Extraction/ GC-FPD	350	1.0	1 x G300	9	96.4
AC Fabric	ALUMINUM	Rotary	HFE-7200	K023-063B	8/19/03	Extraction/ GC-FPD	350	1.0	1 x G300	11	95.2
AC Fabric	ALUMINUM	Rotary	IPA	K023-064A	8/19/03	Extraction/ GC-FPD	350	1.0	1 x G300	42	97.1
AC Fabric	ALUMINUM	Rotary	IPA	K023-064B	8/19/03	Extraction/ GC-FPD	350	1.0	1 x G300	13	99.1
AC Fabric	ALUMINUM	Rotary	M100	K023-065A	8/19/03	Extraction/ GC-FPD	350	1.0	1 x G300	28	98.1
AC Fabric	ALUMINUM	Rotary	M100	K023-065B	8/19/03	Extraction/ GC-FPD	350	1.0	1 x G300	48	96.7
AC Fabric	ALUMINUM	Rotary	MgO	K023-066A	8/19/03	Extraction/ GC-FPD	350	1.0	1 x G300	24	98.3
AC Fabric	ALUMINUM	Rotary	MgO	K023-066B	8/19/03	Extraction/ GC-FPD	350	1.0	1 x G300	23	98.3

AC Fabric = KoTHmex AW 1101 activated carbon fabric.
M100 = 25 ± 1 mg M100 Powder
MgO = 25 ± 1 mg MgO Nanoparticle Powder

Table 45. Results of VX rotary-wiping tests on CARC-painted stainless steel coupons with M100 reactive sorbent powder, MgO nanoparticle powder, HFE-7200, and IPA.

Activated Charcoal Fabric
Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s
Single coupon per test, test done in duplicate
Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	VX Contamination Density g/m^2	Wiping Program	VX Recovered From Coupon µg	Decon Efficacy %
AC Fabric	CARC	Rotary	None	K023-074A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	800	69.2
AC Fabric	CARC	Rotary	None	K023-074B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	521	80.0
AC Fabric	CARC	Rotary	HFE-7200	K023-075A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	244	90.6
AC Fabric	CARC	Rotary	HFE-7200	K023-075B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	214	91.8
AC Fabric	CARC	Rotary	IPA	K023-076A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	285	89.0
AC Fabric	CARC	Rotary	IPA	K023-076B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	246	90.5
AC Fabric	CARC	Rotary	M100	K023-077A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	384	85.3
AC Fabric	CARC	Rotary	M100	K023-077B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	217	91.7
AC Fabric	CARC	Rotary	MgO	K023-078A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	417	83.4
AC Fabric	CARC	Rotary	MgO	K023-078B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	408	84.3

AC Fabric = KoTHmex AW 1101 activated carbon fabric.
M100 = 25 ± 1 mg M100 Powder
MgO = 25 ± 1 mg MgO Nanoparticle Powder

Table 46. Results of VX rotary-wiping tests on alkyd-painted stainless steel coupons with M100 reactive sorbent powder, MgO nanoparticle powder, HFE-7200, and IPA.

Activated carbon fabric
Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s
Single coupon per test, test done in duplicate
Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	VX Contamination Density g/m^2	Wiping Program	VX Recovered From Coupon µg	Decon Efficacy %
AC Fabric	ALKYD	Rotary	None	K023-080A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	1079	58.5
AC Fabric	ALKYD	Rotary	None	K023-080B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	1085	58.3
AC Fabric	ALKYD	Rotary	HFE-7200	K023-081A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	762	70.7
AC Fabric	ALKYD	Rotary	HFE-7200	K023-081B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	1227	52.8
AC Fabric	ALKYD	Rotary	IPA	K023-082A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	597	77.0
AC Fabric	ALKYD	Rotary	IPA	K023-082B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	697	73.2
AC Fabric	ALKYD	Rotary	M100	K023-083A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	1257	51.7
AC Fabric	ALKYD	Rotary	M100	K023-083B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	1106	57.5
AC Fabric	ALKYD	Rotary	MgO	K023-084A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	818	68.5
AC Fabric	ALKYD	Rotary	MgO	K023-084B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	1330	48.9

AC Fabric = KoTHmex AW 1101 activated carbon fabric.
M100 = 25 ± 1 mg M100 Powder
MgO = 25 ± mg MgO Nanoparticle Powder

Table 47. Results of VX rotary-wiping tests on nylon webbing samples with M100 reactive sorbent powder, MgO nanoparticle powder, HFE7200, and IPA.

Activated carbon fabric
Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s
Single coupon per test, test done in duplicate
Indoor (low) HD contamination density – 1.0 g/m²
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	VX Contamination Density g/m^2	Wiping Program	VX Recovered From Coupon µg	Decon Efficacy %
AC Fabric	NYLON WEB	Rotary	No Powder	K023-068A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	67	95.4
AC Fabric	NYLON WEB	Rotary	No Powder	K023-068B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	46	96.9
AC Fabric	NYLON WEB	Rotary	HFE-7200	K023-069A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	213	85.3
AC Fabric	NYLON WEB	Rotary	HFE-7200	K023-069B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	259	82.1
AC Fabric	NYLON WEB	Rotary	IPA	K023-070A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	225	84.5
AC Fabric	NYLON WEB	Rotary	IPA	K023-070B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	135	90.7
AC Fabric	NYLON WEB	Rotary	M100	K023-071A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	130	91.1
AC Fabric	NYLON WEB	Rotary	M100	K023-071B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	70	95.2
AC Fabric	NYLON WEB	Rotary	MgO	K023-072A	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	41	97.2
AC Fabric	NYLON WEB	Rotary	MgO	K023-072B	8/22/03	Extraction/ GC-FPD	350	1.0	1 x G300	53	96.3 3

AC Fabric = KoTHmex AW 1101 activated carbon fabric.
M100 = Reactive Sorbent Powder
MgO = Nanoparticle Powder

Table 48. Results of TGD rotary-wiping tests with aluminum coupons with M100 reactive sorbent powder, MgO nanoparticle powder, HFE-7200, and IPA.

Activated carbon fabric Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s Single coupon per test, test done in duplicate Indoor (low) HD contamination density – 1.0 g/m^2 Sampling and analysis methods – extraction and GC-FPD analysis											
Wiping Material	**Test Surface**	**Wipe Method**	**Solvent/Decon**	**Test No.**	**Date**	**Sampling Method**	**Total Mandrel Weight g**	**TGD Contamination Density g/m^2**	**Wiping Program**	**GD Recovered From Coupon µg**	**Decon Efficacy %**
AC Fabric	ALUMINUM	Rotary	None	K023-088A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	130	90.6
AC Fabric	ALUMINUM	Rotary	None	K023-088B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	114	91.7
AC Fabric Double Layer	ALUMINUM	Rotary	None	K023-093A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	96	93.0
AC Fabric Double Layer	ALUMINUM	Rotary	None	K023-093B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	60	95.7
AC Fabric	ALUMINUM	Rotary	HFE-7200	K023-089A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	3	99.8
AC Fabric	ALUMINUM	Rotary	HFE-7200	K023-089B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	4	99.7
AC Fabric	ALUMINUM	Rotary	IPA	K023-090A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	2	99.9
AC Fabric	ALUMINUM	Rotary	IPA	K023-090B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	7	99.5
AC Fabric	ALUMINUM	Rotary	M100	K023-091A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	13	99.0
AC Fabric	ALUMINUM	Rotary	M100	K023-091B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	5	99.7
AC Fabric	ALUMINUM	Rotary	MgO	K023-092A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	3	99.8
AC Fabric	ALUMINUM	Rotary	MgO	K023-092B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	4	99.7

AC Fabric = KoTHmex AW 1101 activated carbon fabric.
M100 = 25 ± 1 mg M100 Powder
MgO = 25 ± 1 mg MgO Nanoparticle Powder

Table 49. Results of TGD rotary-wiping tests on CARC-painted stainless steel coupons with M100 reactive sorbent powder, MgO nanoparticle powder, HFE-7200, and IPA.

Using Activated carbon fabric
Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s
Single coupon per test, test done in duplicate
Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	TGD Contamination Density g/m^2	Wiping Program	GD Recovered From Coupon µg	Decon Efficacy %
AC Fabric	CARC	Rotary	None	K023-101A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	95	96.2
AC Fabric	CARC	Rotary	None	K023-101B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	89	96.4
AC Fabric	CARC	Rotary	HFE-7200	K023-102A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	78	96.8
AC Fabric	CARC	Rotary	HFE-7200	K023-102B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	71	97.1
AC Fabric	CARC	Rotary	IPA	K023-103A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	46	98.1
AC Fabric	CARC	Rotary	IPA	K023-103B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	61	97.5
AC Fabric	CARC	Rotary	M100	K023-104A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	46	98.1
AC Fabric	CARC	Rotary	M100	K023-104B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	50	98.0
AC Fabric	CARC	Rotary	MgO	K023-105A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	46	98.1
AC Fabric	CARC	Rotary	MgO	K023-105B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	24	99.0

AC Fabric = KoTHmex AW 1101 activated carbon fabric.
M100 = 25 ± 1 mg M100 Powder
MgO = 25 ± 1 mg MgO Nanoparticle Powder

Table 50. Results of TGD rotary-wiping tests on alkyd-painted stainless steel coupons with M100 reactive sorbent powder, MgO nanoparticle powder, HFE-7200, and IPA.

Activated carbon fabric
Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s
Single coupon per test, test done in duplicate
Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	TGD Contamination Density g/m^2	Wiping Program	TGD Recovered From Coupon µg	Decon Efficacy %
AC Fabric	ALKYD	Rotary	None	K023-107A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	307	87.6
AC Fabric	ALKYD	Rotary	None	K023-107B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	339	86.3
AC Fabric	ALKYD	Rotary	HFE-7200	K023-108A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	308	87.6
AC Fabric	ALKYD	Rotary	HFE-7200	K023-108B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	398	83.9
AC Fabric	ALKYD	Rotary	IPA	K023-109A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	149	94.0
AC Fabric	ALKYD	Rotary	IPA	K023-109B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	159	93.6
AC Fabric	ALKYD	Rotary	M100	K023-110A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	184	92.6
AC Fabric	ALKYD	Rotary	M100	K023-110B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	165	93.3
AC Fabric	ALKYD	Rotary	MgO	K023-111A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	139	94.4
AC Fabric	ALKYD	Rotary	MgO	K023-111B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	298	88.0

AC Fabric = KoTHmex AW 1101 activated carbon fabric.
M100 = 25 ± 1 mg M100 Powder
MgO = 25 ± 1 MgO Nanoparticle Powder

Table 51. Results of TGD rotary-wiping tests on nylon webbing samples with M100 reactive sorbent powder, MgO nanoparticle powder, HFE-7200, and IPA.

Activated carbon fabric
Rotary G300 wiping program – 4 clockwise/counterclockwise revolutions at 1.0 rev/s
Single coupon per test, test done in duplicate
Indoor (low) HD contamination density – 1.0 g/m^2
Sampling and analysis methods – extraction and GC-FPD analysis

Wiping Material	Test Surface	Wipe Method	Solvent/Decon	Test No.	Date	Sampling Method	Total Mandrel Weight g	TGD Contamination Density g/m^2	Wiping Program	TGD Recovered From Coupon µg	Decon Efficacy %
AC Fabric	NYLON WEB	Rotary	None	K023-095A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	130	90.6
AC Fabric	NYLON WEB	Rotary	None	K023-095B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	142	89.7
AC Fabric	NYLON WEB	Rotary	HFE-7200	K023-096A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	1100	20.1 (?)
AC Fabric	NYLON WEB	Rotary	HFE-7200	K023-096B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	385	72.0
AC Fabric	NYLON WEB	Rotary	IPA	K023-097A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	432	68.6
AC Fabric	NYLON WEB	Rotary	IPA	K023-097B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	222	83.9
AC Fabric	NYLON WEB	Rotary	M100	K023-098A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	152	88.9
AC Fabric	NYLON WEB	Rotary	M100	K023-098B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	103	92.6
AC Fabric	NYLON WEB	Rotary	MgO	K023-099A	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	181	86.9
AC Fabric	NYLON WEB	Rotary	MgO	K023-099B	8/28/03	Extraction/ GC-FPD	350	1.0	1 x G300	272	80.3

AC Fabric = KoTHmex AW 1101 activated carbon fabric.
M100 = 25 ± 1 mg M100 Powder
MgO = 25 ± 1 mg MgO Nanoparticle Powder

Table 52. Summary of comparative rotary-wiping tests.

Agent	Wipe or Decon	Agent Decontamination Efficacy, %			
		Surface			
		Aluminum	CARC	Alkyd	Nylon
HD	Dry AC Fabric	99.9	99.3	55.3	99.1
	AC Fabric + HFE-7200	>99.9	98.7	65.6	95.8
	AC Fabric + IPA	99.9	98.2	78.0	89.1
	M295/M100	99.3	98.0	55.9	93.5
	MgO	99.9	99.0	40.5	96.3
	Dry Scotch-Brite	92.9	93.4	7.2	-
	Scotch-Brite + HFE-7200	99.9	91.4	19.0	-
	Scotch-Brite + IPA	>99.9	97.4	56.3	-
	M295/M100	99.8	99.4	48.7	-
	MgO	99.9	97.3	13.3	-
VX	Dry AC Fabric	96.0	74.6	58.4	96.1
	AC Fabric + HFE-7200	95.8	91.2	61.8	83.7
	AC Fabric + IPA	98.1	89.8	75.1	87.6
	M295/M100	97.4	88.5	54.6	93.1
	MgO	98.3	83.9	58.7	96.7
TGD	Dry AC Fabric	91.2	96.3	86.9	90.1
	AC Fabric + HFE-7200	99.8	97.0	85.7	72.0
	AC Fabric + IPA	99.7	97.8	93.8	76.3
	M295/M100	99.3	98.0	92.9	90.7
	MgO	99.7	98.6	91.2	83.6

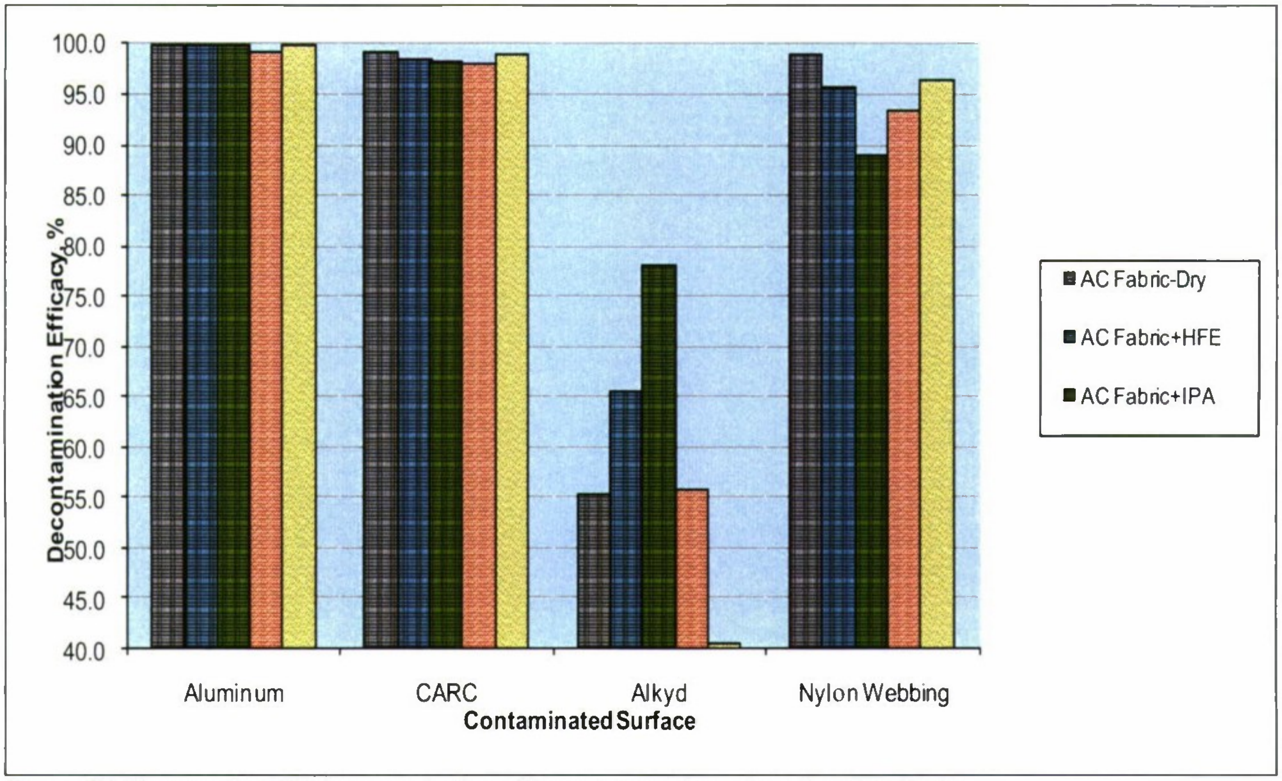

Figure 26. Comparative HD decontamination efficacy test results activated carbon fabric.

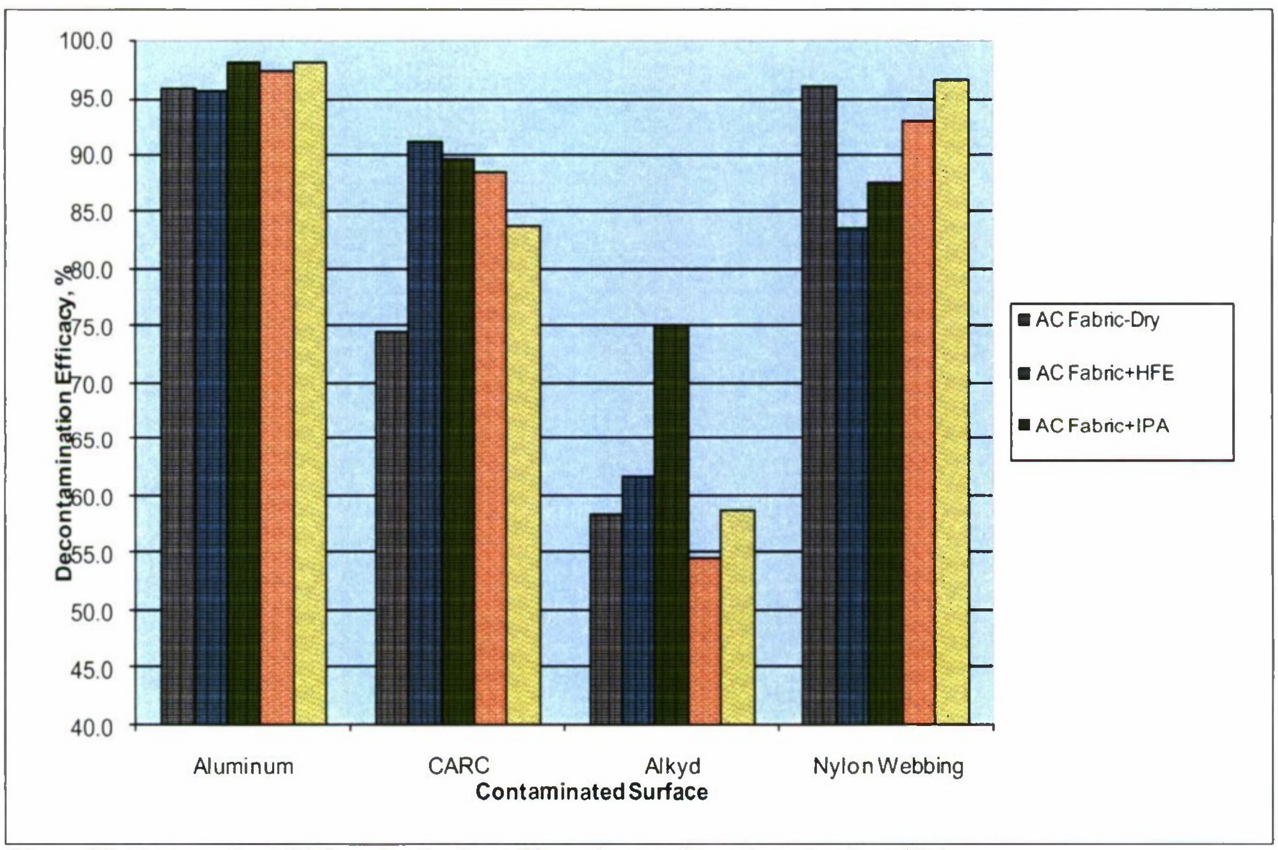

Figure 27. Comparative VX decontamination efficacy test results activated carbon fabric.

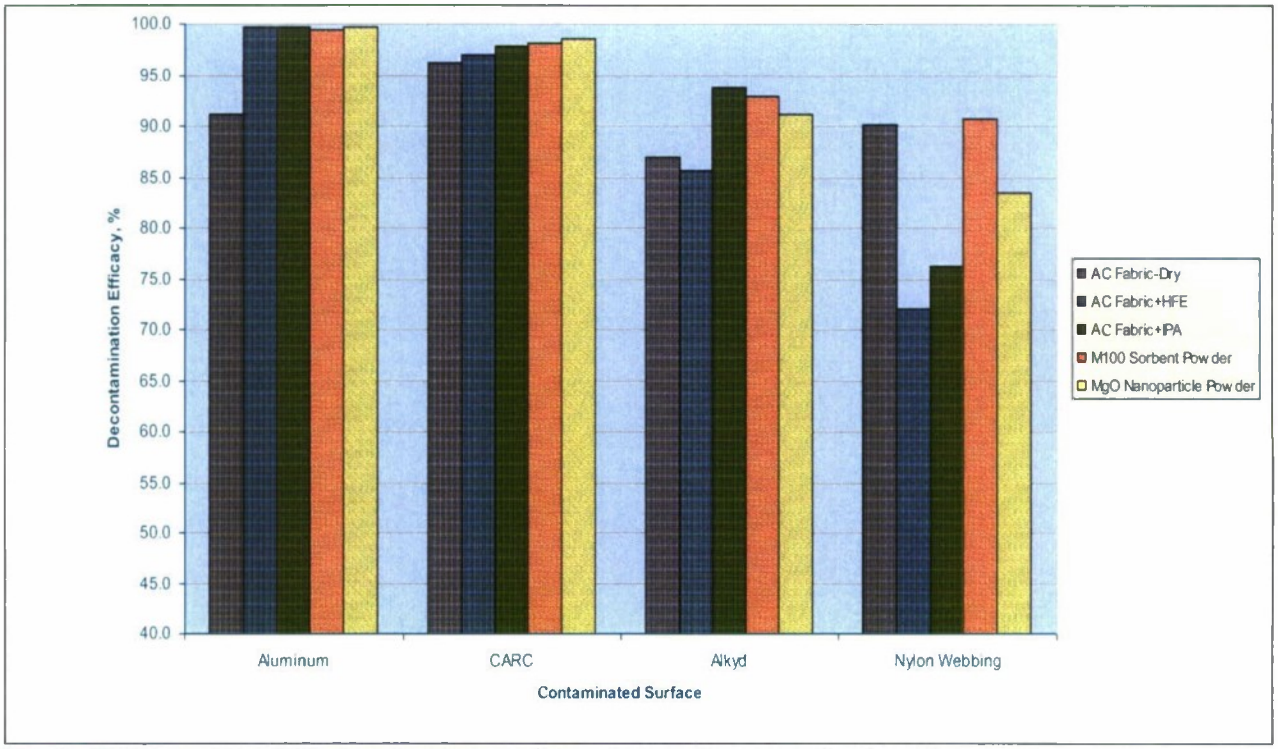

Figure 28. Comparative TGD decontamination efficacy test results activated carbon fabric.

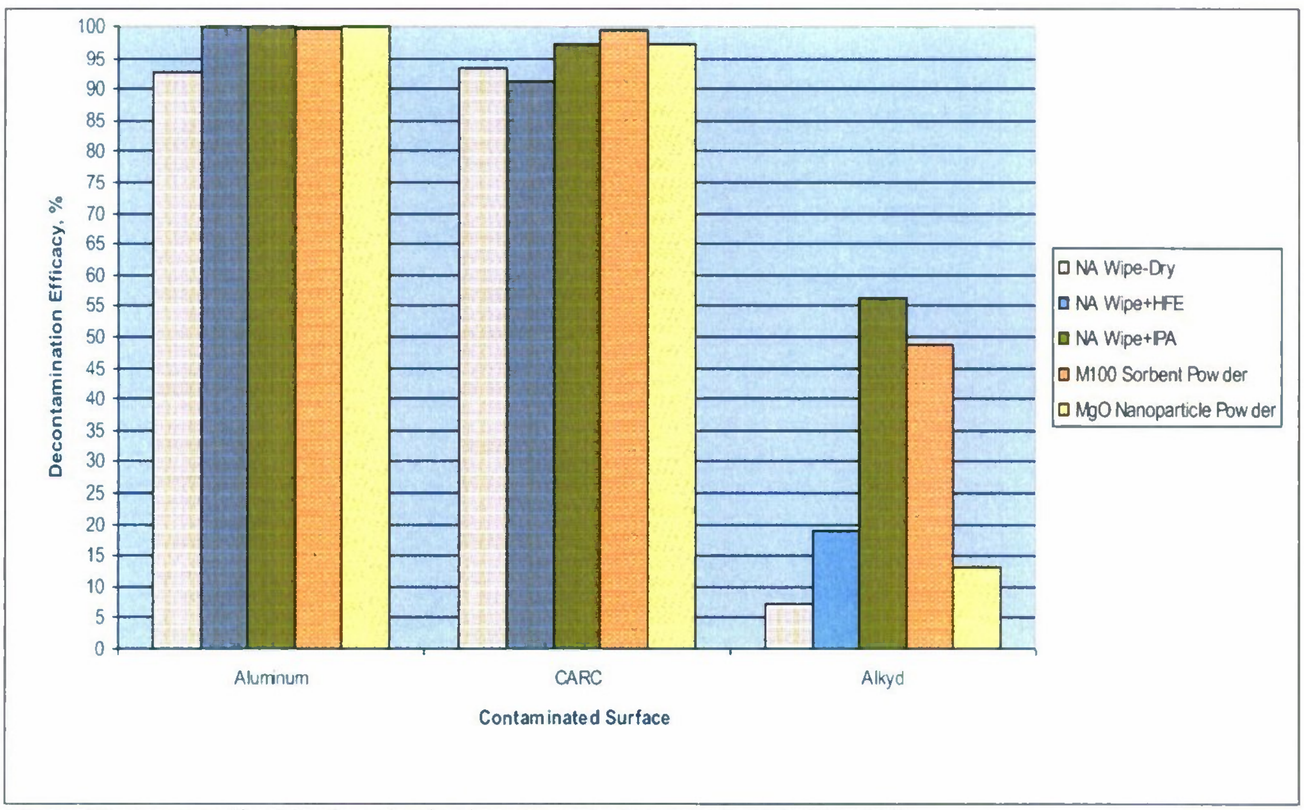

Figure 29. Comparative HD decontamination efficacy test results Scotch-Brite 2021.

7.8.3 Discussion of Test Results

Major conclusions that can be drawn from the results of the comparative rotary-wiping tests are as follows:

- Either dry and/or solvent-moistened, activated carbon fiber wipes were found to effectively remove:
  - >99% of the HD or TGD agent contamination and >98% of the VX contamination from the non-absorptive aluminum test coupons.
  - >97% of the HD or TGD agent contamination and >91% of the VX contamination from the low-agent-absorptive CARC-painted test panels
  - >96% of the HD or VX agent contamination and >90% of the TGD contamination from the relatively low-agent-absorptive Nylon test material.
  - >93% of the TGD agent contamination from the agent-absorptive, alkyd-painted test panels.
- HD and VX decontamination efficacies were generally poor in the tests with alkyd-painted test panels—ranging from 40 to 78%.
- Within the variability of the test results, HFE-7200 essentially matched the effectivity of isopropyl alcohol (IPA) as a wipe solvent for removing all three of the agents tested from the non-absorptive surface (aluminum) and low-agent-absorptive surfaces (CARC and Nylon). IPA was more effective as a wipe solvent than HFE-7200 in removing each of three agents tested from the agent-absorptive surface (alkyd).
- With all three agents and on all four test surfaces, the agent decontamination efficacies of the dry and/or solvent-moistened, activated carbon fiber wipes were equivalent to that of the M295/M100 sorbent powder or the MgO nanoparticle powder.
- With all three agents and on all four test surfaces, the agent decontamination efficacies of the MgO nanoparticle powder were equivalent to that of the M295/M100 sorbent powder.
- Within the wipe parameters of the comparative rotary-wiping tests with HD, and the variability of the test results, the non-adsorptive Scotch-Brite wipes were as effective as the adsorptive, activated-carbon-fabric wipes, especially on the non-absorptive aluminum surface and the low-agent absorptive CARC surface.
- For all three agents, the greatest agent decontamination efficacies were observed on the non-absorptive aluminum surfaces.
- The relative agent decontamination efficacies on the three absorptive surfaces appeared to be agent-dependent. The approximate overall ordering of the absorptive test surfaces (from higher to lower agent decontamination efficacies) by agent were:

- HD: CARC slightly > Nylon >> Alkyd
- VX: CARC ≅ Nylon > Alkyd
- TGD: CARC slightly >Alkyd ≥ Nylon

In the VX and TGD comparative rotary-wiping tests on non-absorptive aluminum surfaces, a dry two-ply activated-carbon-fabric was inserted into the test matrix to compare with the dry single-ply activated-carbon-fabric wipe. Little difference in decontamination efficacies were observed between a single-ply and a two-ply wipe:

- VX decontamination efficacy: Single Ply – 96%, Two-Ply – 94%
- TGD decontamination efficacy: Single Ply – 91%, Two-Ply – 94%

7.8.4 Robustness and Shedding of Wipes

In the comparative rotary-wiping tests, as in all of the earlier agent wipe tests under this program (but not yet noted in this report), both the activated carbon fabric wipes and the Scotch-Brite™ wipes shed some fibers onto the test surfaces during wiping. The fibers that were shed appeared to come from the unseamed edges of the wipes, which became frayed when the wipe swatches were cut to size from larger swatches of the fabrics with a pair of scissors. The extent of shedding was much greater for the activated carbon fabric wipes than it was for the Scotch-Brite™ wipes, which actually shed very little and only periodically. The shredding occurred whether the wipes were dry or solvent moistened.

The activated carbon felt wipes (which were not carried forward for evaluation in the comparative rotary-wiping tests), shed much more extensively on the test surfaces than the activated carbon fabric wipes. The activated carbon felt wipes appeared to leave activated carbon dust or powder on the test surfaces after wiping. In addition, it was observed that the activated-carbon-felt wipes were prone to tearing easily when they were being mounted on the rotary wiping mandrel or linear wiping block.

8. CONCLUSIONS

Single-ply, carbon-based adsorptive wipes, either dry or moistened with solvent are effective in the surface removal of the CA agents HD, TGD, and VX from non-absorptive aluminum coupons, CARC-painted panels, and nylon webbing. The wipes are much less effective in the surface removal of CA agents from absorptive surfaces, such as alkyd-painted panels or agent-absorbing plastics, or polycarbonate in the case of HD.

Either dry and/or solvent-moistened, activated carbon fiber wipes were found to effectively remove:

- >99% of the HD or TGD agent contamination and >98% of the VX contamination from the non-absorptive aluminum test coupons.
- >97% of the HD or TGD agent contamination and >91% of the VX contamination from the low-agent-absorptive CARC-painted test panels.
- >96% of the HD or VX agent contamination and >90% of the TGD contamination from the relatively low-agent-absorptive nylon test material.

- >93% of the TGD agent contamination from the agent-absorptive alkyd-painted test panels.

HD and VX decontamination efficacies were generally poor in the tests with alkyd-painted test panels—ranging from 40 to 78%.

Enhanced agent decontamination was achieved by the application of multiple wipe sequences, the most basic of which was a solvent-moistened wipe followed by a dry wipe.

On non-absorptive and low-agent-absorptive surfaces, HFE-7200 was nearly as effective as a wipe solvent as isopropyl alcohol (IPA). Because HFE-7200 is nonflammable, essentially nontoxic, and generally non-hazardous to personnel, it has a low environmental impact and is compatible with a wide range of metals, plastics, and elastomers. HFE-7200 would be the solvent of choice in a sensitive-equipment decontamination wipe system.

After completion of a wipe test, agent vapor off-gas monitoring of the used wipes was done before the contaminated wipe was bagged and sealed for future disposal. This monitoring indicated a relatively low potential for post-wipe agent-vapor contamination hazard from the used wipe.

HD vapor concentrations over a HD-contaminated, non-absorptive aluminum surface can be reduced to near or below 1.0 TWA (the allowable exposure limit at the time the of the test program) after wiping.

GD vapor concentrations over a TGD-contaminated non-absorptive aluminum surface can be reduced to the same absolute concentration levels (in terms of mass per unit volume, mg/m^3) as HD. However, because the allowable exposure level of GD is 100 times lower than the allowable exposure level for HD, (on the basis of the then-applicable AELs in AR 385-61) 0.003 mg/m^3 for HD and 0.00003 mg/m^3 for GD, surface wiping cannot reduce the GD vapor concentration over a wiped surface to non-hazardous levels. And because the allowable exposure level of VX is another factor of three lower than that of GD, the use of agent vapor off-gassing to assess the effectiveness of a Block III sensitive equipment decontamination procedure, in terms of residual agent vapor hazard, will be feasible among the common threat agents for HD contamination only.

In control tests, activated carbon fiber wipes were equivalent to agent decontamination efficacies obtained with the current M295/M100 reactive sorbent powder or with MgO nanoparticle powder on most of the test surfaces and agents that were evaluated.

In a limited set of abrasion tests, neither the M295/M100 reactive sorbent powder nor the MgO nanoparticle powder showed any visible evidence of gross surface scratching of either polycarbonate or first surface mirrors. However, the possibility still exists for surface micro-scratching of sensitive optoelectronic equipment by the powders, as well as the potential for powder particulates to migrate into and contaminate the interiors of some items of sensitive electronic equipment. Thus, for the decontamination of sensitive optoelectronic equipment, a solvent-wipe decontamination system would seem to be inherently superior to a sorbent-based decontamination system.

The major disadvantages of the activated carbon fabric wipes, relative to some other types of wiping materials such as 3M's Scotch-Brite™ 2021, were that the ACF fabric wipes were somewhat less robust and tended to shed (though not severely) chemical-agent-contaminated fibers during the wiping process—an undesirable and potentially dangerous problem. Effective decontaminant wipes will need good mechanical properties and remain intact without shredding or tearing during potentially severe mechanical handling.

9. RECOMMENDATIONS FOR FUTURE WORK

Recommendations for future work include the following:

- Repeat the comparative rotary wipe test study with additional replicates and a wider range of test surfaces to confirm. Expand the results of the current study and reduce the variability of the test results.

- Conduct an identical set of comparative linear-wiping tests with the same extended range of wipe materials and reference decontaminants, CA agents, and test surfaces as in the repeat comparative rotary-wiping tests.

- Conduct a more extensive set of linear and/or rotary-wiping tests with CA agents to optimize the solvent loading on the wipes, wipe speed, wipe contact time, and number of wipes.

- Conduct a more detailed set of abrasion tests on a wider range of materials with the candidate wipe materials, reactive sorbent powder, and nanoparticle powder.

- Conduct comparative CA-agent wipe tests with both the conventional GC-based residual-agent determination techniques described above in this report (Volume I) and with the fluorescent-dye photographic imaging techniques used with the VX simulant diethylphthalate (DEP) described in Volume II of this report. Correlate the two techniques. The accurate quantitative determination of agent surface removal efficiency by the fluorescent-dye/photographic imaging technique would significantly reduce the time and expense to perform a wipe test and would greatly increase the number of tests that can be conducted concurrently, resulting in a tremendous increase in test throughput.

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ACRONYMS

ACAMS	Automatic Continuous Air-Monitoring System
ACF	Area Cost Factor or Activated Carbon Fiber
AEL	Airborne Exposure Limit
CA	Chemical Agent
CARC	Chemical Agent Resistant Coating
CDD	Capability Development Document
COTS	Commercial Off the Shelf
DAAMS	Depot Area Air-Monitoring System
DEP	Fluorescent diethyl phthalate
ECBC	U.S. Army Edgewood Chemical Biological Center
ESI	Entropic Systems, Inc.
GC-PID	Gas Chromatography-Flame Ionization Detector
GC-FPD	Gas Chromatography- Flame Photometric Detector
GD	Soman, non-persistent agent
HD	Distilled mustard agent
HDPE	high density polyethylene
HFE	hydrofluoroether
IPA	Isopropyl alcohol
JMDS	Joint Material Decontamination System
JPID	Joint Platform Interior Decontamination
JPM	Joint Program Management
JS	Joint Service
JSSED	Joint Service Sensitive Equipment Decontamination
JSTO	Joint Science and Technology Office
KPP	Key Performance Parameters
MINICAMS	Miniature Continuous Air-Monitoring System
MOA	Memorandum of Agreement
NRT	Near Real Time
ORD	Operational Requirements Documents
PC	Personal Computer
PDVI	Portable Decontaminant for Vehicle Interiors
SRI	Southern Research Institute
TIM	Toxic Industrial Material
TTA	Technology Transition Agreement
TWA	Time Weighted Average
VX	Methylphophonothioic acid, persistent nerve agent

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APPENDIX A

DETERMINATION OF WEIGHT OF HFE-7200 SPRAYED ONTO WIPES IN ROTARY-WIPING TESTS

Determination of Weight of HFE-7200 Sprayed onto Wipes in Rotary-Wiping Tests

The weight of HFE-7200 sprayed onto each of the three wipes used in the wiping tests was determined. Ten separate measurements of the weight of HFE-7200 sprayed onto 3M Scotch Brite 2021 fabric wipes, KoTHmex AW 1101-activated carbon fabric wipes, and KoTHmex AM 1132-activated-carbon-felt wipes were determined gravimetrically for each material. In each measurement, a pre-cut 4.5 x 4.5 in. swatch of wipe material was weighed on an analytical balance. The wipe was attached to the rotary-wiping mandrel as in an actual test, the exposed bottom surface of the mandrel-mounted wipe was sprayed with HFE-7200 from an aerosol can of the solvent in the same manner as in an actual test, and then the wipe was removed from the mandrel and re-weighed. The spraying procedure consists of spraying the exposed bottom surface of the mandrel-mounted wipe from the spray can in a single clockwise rotation over a period of about 2 s from a distance of about 3 in. until all of the exposed wipe surface was moistened ("wet") with solvent (but not dripping), as determined by visual observation.

The measured weight of HFE-7200 retained by each wiping swatch is shown below:

Material	Weight
Scotch Brite 2001	7.1 ± 0.8 g
KoTHmex AW 101 Activated Carbon Fabric	4.6 ± 0.4 g
KoTHmex AM 1132-activated Carbon Felt	6.9 ± 0.5 g

The retained weight of HFE-7200 on the activated carbon fabric is lower than the retained weight on each of the other two materials because of the weight and open weave of the fabric.

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APPENDIX B

SEMI-QUANTITATIVE DETERMINATION OF MANUAL WIPING FORCE

B.1 Semi-Quantitative Determination of Manual Wiping Force

A semi-quantitative determination was made of the force applied by an individual during a manual wiping procedure. The tests were conducted with 4.5 x 4.5 in. swatches of 3M Scotch-Brite™ 2001 wiping cloths (the dimensions of the wipes used in the tests with the rotary-wiping test apparatus).

In the tests two different laboratory staff personnel simulated the manual wiping of a spilled liquid on the balance pan of a 70 lb capacity Friden Model 8710 Computing scale. The manual weight applied to the surface of the balance pan during the simulated wiping procedure was monitored and recorded to simulate the force that a human would use to wipe a surface. Wipes one and two were placed on the scale, and the scale was then zeroed. With the scale zeroed, the person conducting the simulated wiping then placed his right hand on the scale and began wiping the surface of the scale while a second person recorded the force (weight) the person used to wipe the surface. Three weights were recorded during each simulated wiping trial. Two wipes with slightly differing weights were used to account for any differences in the weight of the material and the amount of pressure used.

The average pooled applied wiping weight over 24 separate determinations was 2.4 ± 0.8 lbs (1.1 ± 0.4 kg). On the basis of this experiment, lead sheeting was purchased to punch out circular "washers" to slip over the shaft of the rotary wiping mandrel to increase the weight of the mandrel up to about 1.1 kg for future wipe testing.

- Wipe Material: 3M Scotch-Brite™ 2001
- Dimensions: 4.5 x 4.5 in.
- Weight of Wipe 1: 3.7510 g
- Weight of Wipe 2: 4.0320 g

Trial 1 - With wiping personnel looking at the scale as they wiped the scale surface:

Applied Force			
Person 1		Person 2	
Wipe 1	Wipe 2	Wipe 1	Wipe 2
2 lbs. 4.5 oz	2 lbs. 7.0 oz	1 lb. 5.0 oz	2 lbs. 5.5 oz
2 lbs. 9.0 oz	2 lbs. 13 oz	1 lb. 8.0 oz	2 lbs. 4.0 oz
2 lbs. 5.0 oz	2 lbs. 15 oz	1 lb. 9.0 oz	2 lbs. 7.5 oz

Trial 2 - With wiping personnel unable to see the weight display on the scale (the second person covered the scale from the "wiper" and recorded the weight):

Applied Force			
Person 1		Person 2	
Wipe 1	Wipe 2	Wipe 1	Wipe 2
1 lb. 14 oz	3 lb. 5.0 oz	2 lb. 5.0 oz	2 lbs. 8.0 oz
2 lb. 4.5 oz	4 lb. 2.0 oz	2 lb. 6.0 oz	2 lbs. 9.0 oz
1 lb. 8.5 oz	4 lb. 6.0 oz	2 lb. 10 oz	2 lbs. 8.0 oz

Pooled Average: 2.5 ± 0.7 lb. (1.1 ± 0.3 kg)